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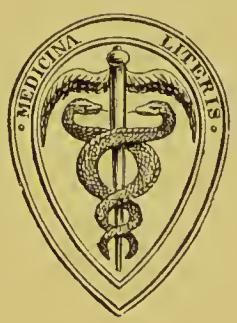
AND ITS TREATMENT

AN ESSAY

BY

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PREFACE.

This essay requires but few words of preface. Some time back my friend Mr. William Lang suggested to me, whilst I was acting as his Clinical Assistant at the Royal London Ophthalmic Hospital, that I would undertake an inquiry on the subject of squint similar to that already made by himself and Dr. Barrett, the results of which appeared in the 'Reports' of the same Hospital in 1888. The cases, therefore, as they came up in Mr. Lang's *Clinique* were used for this purpose.

But though carried out on similar lines this investigation owes nothing to its predecessor, and the results of the two were only compared when the later one was complete. The general effect has been that, whilst in many respects the same conclusions have been reached, some differences have not failed to show themselves. To assist comparison the points both of agreement

and of divergence have been carefully indicated by means of footnotes.

That the results obtained were not always easy to explain will be obvious enough, nor may the explanations suggested always appear satisfactory; yet it may be claimed that every effort has been made to arrive at the truth without any shirking of difficulties, or any special pleading on behalf of a preconceived opinion.

E. H.

40, Wimpole Street;
July, 1897.

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CONVERGENT STRABISMUS.

SECTION I.

GENERAL CONSIDERATIONS.

Strabismus has been spoken of as "a threshed-out subject." Such a phrase is altogether misleading. It not only implies that our knowledge of its phenomena is fairly complete, but that the causation and mutual relations of those phenomena have been determined, and a systematic method of treatment deduced therefrom. Yet it may be doubted whether within the range of ophthalmology there is any subject which more requires investigation, or which gives occasion for greater varieties of treatment.

In regard to convergent strabismus we may, for instance, ask whether the degree of the hypermetropia which is almost invariably present has any direct influence upon the extent of the squint, upon the period of its onset, or upon its curability; or whether the refractive inequality of the two eyes has any bearing upon the same points. And as to the most vexed question of all, the

amblyopia usually observable in a deviating eye, and its origin, the simple inquiry may be made whether it always exists.

So, again, the generally accepted theory of the pathology of convergent squint by no means accounts for all the ascertained facts. That the existence of hypermetropia involves a constant effort of accommodation in order that distinct vision may be produced; that when the hypermetropia exceeds a certain degree, sufficient accommodation can only be obtained by the association of a certain amount of convergence, binocular vision being thus sacrificed and strabismus induced; and that a relative defect of some kind determines which eye shall deviate, is the view generally, though not universally, accepted. Yet apart from the old objection that this theory does not explain why it is that all hypermetropes do not squint, it may be pointed out that it is difficult by means of it to account for those cases in which the hypermetropia is of very moderate degree, or for those, whether alternating or monolateral, in which the two eyes are as nearly as possible equal in every respect.

If there is much, therefore, that is still unsettled in regard to the pathology of strabismus, it is equally the case that, in this country at least, no systematic line of treatment is generally followed. There are two principal methods of dealing with strabismus—by the use of spectacles, and by operation. The latter has been much

longer employed, and was, indeed, established before the former was thought of. Its great advantages have helped to maintain it in a position of supremacy, for it is easily carried out, and its results are immediate and striking, whilst the other is troublesome, tedious, and not always successful. It is natural, therefore, that spectacles should be resorted to chiefly when operation is objected to, or as a mere supplement to operation. Nevertheless, the drawbacks to operation as a primary measure are most serious. A tenotomy performed to correct a moderate amount of convergence when no glasses have been previously worn, will not unfrequently produce a divergence worse than the original deformity. If in a case presenting a high degree of convergence, it does not at once bring the optic axes parallel, some additional proceeding will be employed with the possible result of causing them to diverge. In either case not only will further operative measures be required, but a hindrance will be placed in the way of the subsequent employment of glasses, whose effect it will be difficult to regulate. Moreover, the age at which an operation is considered justifiable is usually determined not so much by the history of the patient as by the predilection of the surgeon, or the urgency of the parent.

In truth, the subject of strabismus is a very complex one. There are many factors at work in producing and maintaining the condition, of

whose relative share therein we are ignorant, and whose mutual action it is difficult to ascertain. To collect all the possible data in a large number of cases, and then determine the average influence of each of them, would be a task of great magnitude; but until it has been achieved we shall probably remain in ignorance of the ultimate causation of the defect. The noting of isolated cases in this, as in other subjects, is of little use; systematic observation of all those available is alone likely to be of service.

The results here given are drawn from observations made on a limited number of cases, such as could be handled without great difficulty, and yet sufficient to neutralise the effect of any accidental error of observation. The cases were noted as they came up for treatment during a period of about two years. Only those which presented decided nebulæ in one or both eyes have been kept out of consideration, the reason for this being the uncertainty that attended the estimation of their vision and refraction. The cases were 144 in number. Of these, 142 were hypermetropes with or without astigmatism, two only were myopes. Constant convergent strabismus was present in 135 of the hypermetropic cases, in seven the convergence was periodic. In 123 instances of the constant form the convergence was always manifested by one eye only, in twelve it alternated between one eye and the other. The whole series may be tabularly arranged thus:

Hypermetropic cases :	
A. Periodic* . . .	7
B. Constant :	
(α) Monolateral . .	123
(β) Alternating . .	12
	142
Myopic cases	2
	144

The proportion of hypermetropes was therefore 98·61 per cent., of myopes 1·38 per cent. Among the constant hypermetropic cases, constituting the great majority of the total number, the monolateral occurred in the proportion of 91·11 per cent., the alternating in that of 8·88 per cent.

The cases were thus dealt with. After the age, family history, the assumed causation, and—when ascertainable—the time of onset had been noted, the degree of strabismus present was measured with the perimeter, and the vision of each eye, whenever possible, made out. Atropine was then prescribed, and a few days later the actual re-

* It may be stated at once that, on account of their tender years, little could be learnt from these periodic cases except the efficiency of spectacle treatment as applied to them. They were all readily cured by the use of glasses, but too young to furnish any useful facts as to vision, and the questions connected therewith. The subsequent discussions, therefore, are based upon the data drawn from the constant cases only.

fraction was estimated by retinoscopy, the amount of convergence again measured, and fully correcting glasses ordered for constant wear. The use of atropine was continued until the patient had begun wearing the glasses. At intervals of three months or more the degree of convergence, both with and without the correcting glasses, was again measured, and the acuteness of vision also noted. Orthoptic training was resorted to whenever it seemed likely to be of service; operations were undertaken only when glasses had been worn for some time, and nothing further was to be expected of them. The difficulties and drawbacks incidental to this line of procedure are not to be ignored. They will be considered in detail hereafter; at present it may be enough to mention that it was possible to carry it out with more than three fourths of all the patients in this series, and to obtain records of treatment extending over periods varying from a few weeks to more than four years, with an average among the constant cases of nearly nineteen months. And even the cases from which, as regards treatment, no results could be obtained, have yet helped to supply some of those data as to history, refraction, and vision, on which the ætiology of strabismus must ultimately rest.

SECTION II.

THE PREVIOUS HISTORY AND ITS INFLUENCE IN MONOLATERAL CONVERGENT STRABISMUS.

We will deal first with that class of cases which is the most numerous, and in some respects the simplest, that in which convergent strabismus is constantly present, and is always manifested by the same eye. We have here a series of such cases, 123 in number.

The first point that suggests itself for inquiry is the age at which the patients first sought for treatment. This was, of course, largely accidental, depending on the negligence or anxiety of the parents, or, in the older cases, on the caprice of the patients themselves. Yet it is worth attention, for this element of age may have some relation to the degree of convergence then attained, and some influence on the efficacy of subsequent spectacle treatment. The following table shows the cases arranged in successive groups according to the age reached on first coming for advice, with the average amount of convergence present in each group.

TABLE I.

Age at first visit.	Number.	Proportion.	Average amount of convergence.
Under 5 years . .	22	17·88 per cent.	20·72°
From 5 to 10 years .	53	43·08 ,,	22·45°
,, 10 to 15 ,, .	28	22·76 ,,	24·89°
,, 15 to 20 ,, .	13	10·56 ,,	26·92°
Over 20 years . .	7	5·69 ,,	18·85°

It will be seen, therefore, that by far the largest group was the second, in which the age ranged from the end of the fifth to the end of the tenth year. It comprised nearly one half of the whole number of cases. This is doubtless to be explained by the circumstance that the period in question embraced the beginning of school-life, when the accommodation was subjected to a new and continuous strain, and the tendency to abnormal convergence thereby received an increased impetus. In each following period the proportion rapidly diminished, probably because, on the one hand, there must be fewer untreated cases left in the later periods of life, and on the other, because as years go by the deformity comes to be regarded as a matter of indifference.

If, however, the older patients were fewer in number than the younger, they presented usually a greater amount of strabismus. In each successive period up to twenty years of age the average degree of convergence steadily increased. That strabismus tends to get worse the longer it is left

to itself, and that, consequently, the older the patient the higher will be the degree of convergence exhibited, may be, and probably is, accepted as a general rule. Nevertheless, it is a rule subject to frequent and striking exceptions. Not only may a high degree of convergence be found at an early age, but a very moderate degree may be present in an adult. In this series the few cases in which the age exceeded twenty years are in direct opposition, as a group, to the action of the rule. This element of age is indeed only one factor out of many affecting the degree of strabismus, and must not be allowed undue importance.

Now the onset of convergent strabismus almost invariably occurs in early life. The older, therefore, a patient affected by it is, the longer will the strabismus have lasted. This inference can be tested in 110 cases of the present series. In regard to these, vague statements as to the previous duration have been rejected and the time when the deviation was first noticed fixed as far as possible by reference to other circumstances in the patients' lives. But since we may be sure that the squint usually remained unobserved until some time after its actual onset, the recorded must be taken as somewhat shorter than the real duration. Table II gives, in reference to these 110 cases, the same data that appeared in Table I, with the addition of the average previous duration of the strabismus.

TABLE II.

Age at first visit.	Number.	Proportion.	Average previous duration.	Average amount of convergence.
		per cent.		
Under 5 years . .	22	20·00	·84 years	20·72°
From 5 to 10 years	48	43·63	3·20 „	22·39°
„ 10 to 15 „	24	21·81	8·33 „	25·91°
„ 15 to 20 „	10	9·09	11·70 „	26·50°
Over 20 years . .	6	5·45	17·00 „	20·33°

The connection between advancing years and length of duration, though not invariable, appears from this to be sufficiently close to justify us in taking the one as usually implying the other. Consequently increased duration generally implies a higher degree of convergence. But bearing in mind the reservations which have to be made, it will be safer to avoid speaking of a law, and to say that there is a tendency for convergent strabismus to increase in amount the longer it has lasted without treatment. The tendency, moreover, has its limits, for in every case there comes a time, sooner or later, when the strabismus ceases to be progressive and becomes stationary. How far the previous duration of convergent strabismus may affect the results of spectacle treatment will be considered when the latter subject is dealt with as a whole.

The age at which a patient first comes for treatment has been spoken of as largely accidental. But there is another age factor which

is by no means, in the same sense, accidental; the age, namely, at which the convergence first manifests itself. In all those cases in which the previous duration was known, the time of onset could be approximately fixed. For the reason already given, the period thus ascertained must be taken as somewhat later than that at which the strabismus first actually appeared. Even so it will be found that in the great majority of these cases the onset occurred during early childhood. In the next table is shown for each year of life the number of those who then first developed convergent strabismus, and the proportion which that number bore to the whole.

TABLE III.

Period of onset.	Number.	Proportion.
During 1st year . . .	11	10·00 per cent.
,, 2nd ,, . . .	13	11·81 ,,
,, 3rd ,, . . .	20	18·18 ,,
,, 4th ,, . . .	26	23·63 ,,
,, 5th ,, . . .	13	11·81 ,,
,, 6th ,, . . .	11	10·00 ,,
,, 7th ,, . . .	10	9·09 ,,
,, 8th ,, . . .	2	1·81 ,,
,, 9th ,, . . .	2	1·81 ,,
,, 14th ,, . . .	1	·90 ,,
,, 18th ,, . . .	1	·90 ,,

It will be noticed that in as many as 10 per cent. of the cases the convergence appeared during the first year of life, that the proportion

rose in each successive year up to a maximum of nearly 24 per cent. in the fourth year, and thence steadily declined, until after the end of the seventh year it became exceptional for this form of strabismus to arise at all.

If the end of the fifth year be taken as a dividing line, and the cases formed into two groups accordingly, we get the following result :

TABLE IV.*

Period of onset.	Number.	Proportion.
Under 5 years . . .	83	75·45 per cent.
Over 5 years . . .	27	24·54 „

In more than three fourths, therefore, of the patients forming this series, strabismus had developed before the end of the fifth year, that is, before regular school life had begun. Can this be accounted for by the usual theory of convergent strabismus? Is the accommodation so severely strained during these early years that its object can only be attained by the sacrifice of binocular vision? The question cannot be properly answered until the refractive conditions have been inves-

* With the figures in this and the preceding table may be compared those given by Messrs. Lang and Barrett ('Roy. Lond. Ophthal. Hosp. Reps.,' vol. xii, p. 140). Of their series of 195 cases, thirty-six, or 18·46 per cent., began to squint during the first year, and thirty-four, or 17·46 per cent., after the fifth year of life. It is clear that in a large proportion of cases, convergent strabismus is developed at a very early period.

tigated, but before undertaking this it will be well to inquire what part other influences may bear in the genesis of convergent strabismus.

Among the most important of these may be counted inheritance. It is an influence that has long been recognised, and of which instances are common enough, but which is yet by no means universally present. Out of 120 of the present cases an hereditary tendency to squint could not be traced in as many as seventy-eight, or 65 per cent.; in thirty-six cases, or 30 per cent., it was clearly present; in the remaining six its existence was doubtful. The classification requires a word of explanation. The hereditary influence was regarded as certainly present when a brother, sister, or a direct ancestor of the patient was found to be the subject of strabismus. It was also taken as present in two instances in which squint was found to exist in more than one family of first cousins on the same side. But its presence was considered doubtful in those cases in which strabismus was discovered affecting a single collateral relative, such as an uncle, aunt, or cousin.* It is

* Messrs. Lang and Barrett ('Roy. Lond. Ophthal. Hosp. Reps.,' vol. xii, p. 137, *et seq.*), found convergent squint existing in the brothers or sisters of the patient in twenty-five out of eighty-seven cases, a proportion of 28·73 per cent. In twenty-two out of seventy-seven instances, or 28·57 per cent., strabismus was found in the parents or the parents' families. We may take it, therefore, that an hereditary tendency can be traced in about 30 per cent. of those affected by this form of squint. A remarkable instance of hereditary transmission is given by them at page 139 of the same volume.

worth mention that in two families strabismus was transmitted for three successive generations. In the first the transmission was from a mother to two sons, and from one of those sons to an only daughter. In the second a mother transmitted her strabismus to a daughter, and through a son who was unaffected to two granddaughters. Such cases, are, however, little more than curiosities of heredity, and many hundreds of family histories would have to be examined before any definite results could be obtained as to the way in which the tendency in question is transmitted. Moreover, the method of transmission is of little moment, the presence of the tendency is itself the important fact.

Now there arises here the practical question as to what is the relative influence of the hereditary tendency in producing strabismus in comparison with other causes. It is, of course, impossible to lay this down in definite terms, but some idea of its extent may be formed by noting its bearing on the period of onset. This can be done by indicating how many of those who in each successive year of life developed strabismus, were subject to an inherited tendency thereto. The following figures will show this (Table V).

It will be seen that the hereditary tendency was present in just half of those patients who developed strabismus before they were two years old, and that the later the period of onset the smaller as a rule was the proportion of those in

TABLE V.

Period of onset.	Inherited tendency present.		Inherited tendency absent.		Inherited tendency doubtful.	
	Number.	Proportion.	Number.	Proportion.	Number.	Proportion.
		per cent.		per cent.		per cent.
During 1st year	5	45·45	6	54·54	0	—
,, 2nd ,,	7	53·84	6	46·15	0	—
,, 3rd ,,	6	30·00	13	65·00	1	5·00
,, 4th ,,	5	19·23	19	73·07	2	7·69
,, 5th ,,	3	23·07	9	69·23	1	7·69
,, 6th ,,	2	18·18	9	81·81	0	—
,, 7th ,,	2	22·22	5	55·55	2	22·22
After 7th ,,	1	16·66	5	83·33	0	—

whom the tendency could be certainly found. We may infer, therefore, that inherited predisposition has a potent influence, not merely in determining whether strabismus shall appear at all, but in causing it to appear at an earlier age than it otherwise might.

Can any importance be attributed to those other influences which parents so often look upon as the exciting cause of strabismus in their children? Many of these have, of course, no significance at all, and need not be dwelt upon. But there are some, such as definite general or local disorders, which are worth a little consideration. No doubt it is often the case that they are coincident only, and act no further than by calling attention to a habit of squinting already present, but till then unobserved. Nevertheless it need not always be so, and if we

remember that strabismus is essentially a disturbance of the nervous centres co-ordinating the movements of certain ocular muscles, it is not difficult to understand the part which such disorders may play in the matter. They may act either by producing general weakness, and therewith a loss of nerve tone, or in the case of localised complaints by exciting irritation in the nerve-centres. In many hypermetropic patients it may well happen that a struggle to maintain binocular vision has been going on for some time, and that the debility following a specific fever, or the irritation caused by some local inflammation, is the proximate cause of an unfavourable issue. It seems worth while, then, to give in tabular form the relative occurrence of such affections among those cases in which the time of onset of the strabismus was known.

TABLE VI.

Supposed proximate cause.	Period of onset of strabismus.								Totals.
	1st year.	2nd year.	3rd year.	4th year.	5th year.	6th year.	7th year.	After 7th year.	
Dentition . . .	1	7	1	—	1	—	1	—	11
Specific fevers . .	—	1	4	6	5	1	1	—	18
Digestive disorders .	—	—	—	2	—	—	—	—	2
Nervous disorders	—	1	1	—	—	—	—	—	2
Accidents . . .	—	—	1	6	1	—	1	—	9
School influences .	—	—	—	—	2	2	—	2	6
Local inflammations	1	—	1	1	—	—	—	1	4
No cause assigned .	9	4	12	11	4	8	7	3	58
Totals . .	11	13	20	26	13	11	10	6	110

We may notice in the first place that in more than half the cases no proximate cause whatever was assigned. Yet it need not be inferred that none existed among all of these. The disorders of childhood are not very carefully noted by parents in the class of life to which these patients belonged, and even when coincident with the onset of the squint they may have been forgotten, whilst such an influence as the beginning of work at school would not often suggest itself as a cause at all.

In fifty-two cases, however, some proximate cause was put forward as provoking the strabismus. In the earliest period, especially during the second year, it was the troubles connected with dentition which were chiefly regarded as such a cause. Considering the serious effect which they often have on the nervous organisation of young children, and the fact that in most of these instances the hereditary element happened to be absent, we may not unreasonably suppose that they may contribute to the disturbance of the relations between the movements of the ocular muscles, if only by making co-ordination more difficult.*

Later on, especially during the middle period from the third to the fifth year, we find the

* That such causes may contribute to the loss of control over the eyes, and that they are often treated "with scant attention," is the opinion of Mr. Priestley Smith ("Ingleby Lectures," 'Brit. Med. Journ.,' 1896, vol. i, p. 1546).

specific fevers to be the most important of these secondary causes. They were, indeed, the most frequent of all; and if any influence is to be attributed to them, it must be, as already suggested, on account of their general debilitating effect.

In the latest period, from the fifth year onwards, school influences come into play, probably more often than this table indicates.

The six instances of accident occurring during the fourth year must be regarded as cases of coincidence, except perhaps one in which an injury was followed by septic infection causing a long illness.

Without insisting, then, on any undue importance as regards these secondary influences, we may, knowing how difficult it sometimes is to account for the presence of strabismus on the usual grounds, fairly say that they ought to be taken into account as possible factors in its development.

Monolateral convergent strabismus, therefore, in the great majority of instances, arises during the earliest years of life, and in no small proportion during the first two years after birth.

Chief among the causes, other than optical or visual defects, inducing its early onset appears to be hereditary tendency; but it is at least possible that local or general maladies may have some influence in determining the time of its appearance.

Once started, it tends, as a general rule, subject to frequent exceptions, to go on increasing in extent the longer it is left without treatment, but sooner or later becomes stationary.

SECTION III.

THE REFRACTION IN MONOLATERAL CONVERGENT STRABISMUS.

Whatever other influences, however, may be at work, it is the presence of hypermetropia which is admitted to be the dominant factor in the causation of convergent strabismus. And it is generally taken for granted that the refractive defect exists in both eyes of a squinting patient, and that it is usually greater in the deviating eye, being associated as regards the latter with a more or less serious defect of vision.

Now, apart from therapeutics, several interesting questions arise in reference to this part of the subject. It is not enough to be aware of the existence of hypermetropia, but we ought to know how it is distributed as between fixing and deviating eyes in general, and also as among individuals. We may inquire whether the degree of the strabismus may have any relation to the extent of the refractive difference between the fixing and the deviating eye, or to the absolute amount of hypermetropia present in either; and further, whether the early development of a convergent squint implies a high degree of

hypermetropia. We may consider lastly how far the refractive defect and the visual defect in a deviating eye are connected with one another.

Out of the 123 cases now under consideration the refraction of all but three was determined objectively, and these three, therefore, have been put aside. The nature of the refractive defect found in the remaining 120 can best be shown thus:

TABLE VII.

Nature of refractive defect.	Fixing eyes.		Deviating eyes.	
	Number.	Proportion.	Number.	Proportion.
		per cent.		per cent.
Simple hypermetropia . . .	48	40·00	30	25·00
Simple hypermetropic astigmatism	—	—	1	0·83
Compound hypermetropic astigmatism	72	60·00	87	72·50
Mixed astigmatism	—	—	2	1·66

Whilst ametropia was present in all the fixing eyes its more complex forms were found in a higher ratio among the deviating ones. And when classified as in Table VIII according to the degree of astigmatism a similar result is obtained. (Table VIII.)

Astigmatism of low degree is more frequent among the fixing eyes, the deviating eyes are more often subject to astigmatism of high degree.

Once more, if we compare those members of each class in which no astigmatism was present,

TABLE VIII.

Degree of astigmatism.	Fixing eyes.		Deviating eyes.	
	Number.	Proportion.	Number.	Proportion.
		per cent.		per cent.
No astigmatism . .	48	40·00	30	25·00
Astigmatism = ·5 D. .	35	29·16	29	24·16
Astigmatism = 1 D. .	19	15·83	23	19·16
Astigmatism over 1 D. .	18	15·00	38	31·66

arranging them according to the degree of their hypermetropia, the same relation will be illustrated.

TABLE IX.

Degree of hypermetropia.	Fixing eyes.		Deviating eyes.	
	Number.	Proportion.	Number.	Proportion.
		per cent.		per cent.
Up to 2 D. . . .	18	37·50	7	23·33
2 D. to 4 D. . . .	15	31·25	10	33·33
4 D. to 6 D. . . .	9	18·75	9	30 00
6 D. to 8 D. . . .	4	8·33	2	6·66
8 D. to 10 D. . . .	2	4·16	2	6·66

Simple hypermetropia of low degree (up to 2 D.) was to be found in a certain number both of the fixing and the deviating eyes, but in a distinctly higher ratio among the former. So, again, hypermetropia of medium degree (2 D. to 6 D.) was present far more often relatively among the deviating than among the fixing eyes. The circumstance that when the higher degrees (6 D.

to 10 D.) are reached the two classes seem to be on a level cannot be considered as of much importance when the paucity of the numbers is taken into account. Moreover, if the astigmatic cases be added, the disadvantage again appears on the side of the eyes which are misdirected.

It is worth while, however, to note that the ametropia may attain as high a degree in the one class of eyes as the other, and this is equally the case whether astigmatism be present or not. The range of refractive defect in a comparison of the fixing and deviating eyes is shown, so far as hypermetropia is concerned, in the following table. The two cases of mixed astigmatism have been left out of account as exceptional.

TABLE X.

Cases classed according to the degree of astigmatism.	Range of defect in lower meridians.	
	Fixing eyes.	Deviating eyes.
No astigmatism . . .	·5 D. to 10·0 D.	1·0 D. to 10·0 D.
Astigmatism = ·5 D. . .	1·0 D. to 7·5 D.	1·0 D. to 10·0 D.
Astigmatism = 1·0 D. .	1·5 D. to 8·0 D.	1·5 D. to 8·0 D.
Astigmatism over 1·0 D. .	2·0 D. to 7·5 D.	0 D. to 8·0 D.

In no case throughout the series of deviating eyes did the hypermetropia reach a higher degree than what could be found among the series of fixing eyes. As a class the former were inferior to the latter, but only by reason of the larger proportion of highly ametropic eyes existing among them. Or, to put it in another way, the

fixing eyes were superior in that they comprised a larger number of those whose refraction approached the normal standard.

How, then, does the case stand as regards individual patients? If the deviating eyes are as a class inferior to the fixing eyes, does it follow that in every patient the eye which squints is more ametropic than the eye which is used for fixation? It is usually assumed that such is the fact, and that this relative deficiency not only decides which eye shall squint, but largely assists in developing the strabismus. The hypermetrope with eyes of unequal refraction sacrifices, it is suggested, the more ametropic eye in order to obtain, by exerting his accommodation to the utmost, clear monocular vision with the less ametropic one, convergent strabismus being the result. But when, though hypermetropia be present, there is no such inequality, the impulse to an excessive effort of accommodation with its associated excess of convergence is overpowered by the desire for binocular vision, and the eyes retain their proper direction. And hence, anisometropia being less common than the reverse condition, it is only in a minority of hypermetropes that convergent strabismus is developed.

This explanation, therefore, is based upon two assumptions: the first, that anisometropia is practically unknown among those hypermetropes who do not squint; the second, that it is always

present in those who do. Yet neither of these assumptions is correct. The former is contradicted by daily experience; for anisometropia, of a degree quite equivalent to that existing in many cases of strabismus, is constantly to be found among hypermetropes who have in spite of it maintained binocular vision. And as to the latter, it has been recognised that convergent squint may occur in patients whose eyes in respect both to refraction and vision are exactly alike.

Yet even when it is admitted that cases exist in which strabismus is associated with equality of refraction, and that in order to account for them some special explanation must be found, it is maintained that they form but an insignificant minority. It becomes important, therefore, to ascertain what kind of ratio they may bear to the number of anisometropic cases. Before doing so with the present series it will be useful to show the distribution of astigmatism as among individuals.

TABLE XI.

Distribution of astigmatism.	Number.	Proportion.
No astigmatism in either eye .	22	18·33 per cent.
Astigmatism in deviating eye only	26	21·66 ,,
Astigmatism in fixing eye only .	8	6·66 ,,
Astigmatism in both eyes . .	64	53·33 ,,

Attention will naturally be drawn in the first place to the third of these divisions, where the

presence of astigmatism in the fixing but not in the squinting eye suggests that the former may occasionally, as regards refraction, be the worse of the two. But in the majority of these cases the astigmatism did not amount to more than ·5 D., and in all but one the deviating eye showed a greater total amount of hypermetropia than its fellow. In spite of the astigmatism, moreover, the vision was invariably better in the fixing eye. The existence of a certain degree of astigmatism in the one eye does not, therefore, necessarily mean its inferiority as an organ of vision to the other.*

But as to this division, and that other comprising the cases which showed astigmatism in the deviating eye only, there can of course be no question of equality of refraction between the two eyes. It is only in the first and last divisions that the absence of anisometropia can be looked for. If now we separate the cases in which the refractive defect was of equal degree in each eye from those in which it was of unequal degree, we get the following figures:

* From the figures given by Messrs. Lang and Barrett, it would seem that these observers found the fixing eye to be worse than its fellow as regards refraction in twenty-six out of eighty-eight cases of "ordinary convergent strabismus," a proportion of 29·54 per cent. ('Roy. Lond. Ophthal. Hosp. Reps.,' vol. xii, p. 17).

Table XII.

Distribution of astigmatism.	Isometropic.		Anisometropic.	
	No.	Proportion.	No.	Proportion.
		per cent.		per cent.
No astigmatism in either eye .	6	5·00	16	13·33
Astigmatism in deviating eye only	—	—	26	21·66
Astigmatism in fixing eye only .	—	—	8	6·66
Astigmatism in both eyes . .	10	8·33	54	45·00
Totals	16	13·33	104	86·65

From these it appears that though a large majority of the cases exhibited anisometropia, usually to the disadvantage of the deviating eye, yet that 16 out of the 120, forming a proportion of more than 13 per cent., showed no inequality as regards refraction. And it must be remembered that these were monolateral cases only, and that if we reckon in the 12 alternating cases also, of which 3, that is, a proportion of 25 per cent., were isometropic, we have out of a total of 132 patients subject to constant convergent strabismus, as many as 19 in whom no anisometropia could be detected. These 19 form a proportion of 14·39 per cent. That is to say, that in one seventh of the whole number some other factor than mere inequality of refraction must be sought for as the proximate cause of the affection. Presuming this series to be fairly representative, the isometropic cases cannot be looked on as an insignificant minority.* And even

* In Messrs. Lang and Barrett's essay the refraction was

should they actually constitute a smaller proportion of the whole class than they do here, their mere existence suggests that even when anisometropia is present, this may not of itself induce the convergence.

But we may go further, and endeavour to make out whether among that large class of cases which is anisometropic the degree of the convergence may bear any relation to the amount by which the eyes differ in refractive power from each other. This is not very easy to do, because of the difficulty in comparing eyes, either or both of which may be astigmatic. When there is no astigmatism in either the difference is of course a simple spherical difference. When also both eyes are astigmatic, but to the same degree, and in the same direction, the difference is again simply spherical. But if neither of these conditions be present it is very difficult to make any satisfactory comparison. For instance, it is common enough to find astigmatism in one eye, but not in the other. In one such case, however, the faulty

considered to be different in the two eyes "only when either the spherical or the cylindrical error in the two eyes differed by at least 1 D." On this basis 107 out of a total of 205 cases, including both the alternating and ordinary varieties, were found to have the refraction alike in the two eyes. If the proportion of 52·19 per cent. of isometropic cases which existed in this series holds good generally, it is clear that inequality of refraction must have far less to do with the production of squint than is generally supposed ('Roy. Lond. Ophth. Hosp. Reps.,' vol. xii, p. 16).

eye may be more hypermetropic in both principal meridians than its fellow; in another it may be less so; in a third it may be more ametropic in one meridian whilst it is less so in the other. When both eyes are astigmatic and in different degrees it is still more difficult to compare them by any method that will apply to all cases alike. For our present purpose it will be sufficient if we attempt nothing of the kind, and confine our attention to those cases in which the refractive difference can be simply expressed in so many dioptres of hypermetropia.

We have here thirty such cases, just one fourth of the whole number, a proportion large enough to indicate the effect of the relation we are inquiring into should it exist. In sixteen of these there was no astigmatism, in the other fourteen the astigmatism was of the same degree, and affected corresponding meridians in each eye. Again we have to note that occasionally the refractive disadvantage may be on the side of the fixing eye, for in three of the former and two of the latter class the squinting eye was slightly the less hypermetropic of the two. If these are to be put aside as anomalous, we have still twenty-five cases left by which to test the possibility of a relation between the degree of the convergence and the extent of the refractive error by which the eyes may differ from each other. An examination of them gives these results :

Table XIII A.

Amount of spherical difference.	No astigmatism in either eye.		Astigmatism the same in either eye.	
	Number.	Average amount of convergence.	Number.	Average amount of convergence.
·5 D.	6	19·16°	3	29·33°
1·0 D.	2	32·50	3	27·33
1·5 D.	2	20·00	4	28·75
2·0 D.	1	15·00	1	15·00
2·5 D.	—	—	—	—
3·0 D.	2	27·50	1	30·00

If the two classes be combined into one the result will stand thus :

Table XIII B.

Spherical difference.	Number.	Average amount of convergence.
·5 D.	9	22·55°
1·0 D.	5	29·40
1·5 D.	6	25·83
2·0 D.	2	15·00
2·5 D.	—	—
3·0 D.	3	28·33

These figures require no explanation. On the face of them it is apparent that the extent of the convergence of the squinting eyes did not depend on the extent by which their hypermetropia exceeded the hypermetropia of the corresponding fixing eyes. And if this was so when the difference in refraction was of a comparatively simple nature, we may assume that it was also

the case when the refractive relations of the eyes were more complex.

But there is a more important refractive element to consider than the mere difference between the eyes. We may give due weight to the influence of anisometropia, and admit not only that it usually determines which eye shall be the one to deviate, but that it may often when strabismus is imminent be the actual deciding factor in its production; yet we have to remember that it is the absolute amount of hypermetropia, exciting the accommodation to continual action, which is the great predisposing cause thereof. Anisometropia is not to be found in all cases of convergent strabismus, hypermetropia is present in all but an infinitesimal minority.

Recognising this, it is natural to inquire whether we may not expect to find some definite relation existing between the cause and its result, between the amount of the hypermetropia and the degree of the convergence. Such a relation we should look for in connection with the fixing rather than the deviating eye. The latter has been sacrificed; it has, if the expression may be used, been put out of play, and the accommodative effort—though distributed equally between the two—will be adjusted exclusively to the requirements of its fellow, now alone used for direct vision. Yet it need not be left out of consideration altogether. For the greater the ametropia of the

fixing eye, the greater as a rule will be that of the deviating eye ; and if therefore there be any correspondence in the case of the former between the amount of this ametropia and the extent of the squint, there should be a similar correspondence, less exact indeed, but traceable, in the case of the latter.

In Table XIV A are classified, according to the amount of hypermetropia present in the fixing eyes, all the 120 cases now under consideration, with subdivisions according to the degree of astigmatism these exhibited. At the same time is shown the average extent of the convergence in each class and subdivision.

The results are such as to confirm in a remarkable way the conclusions which *a priori* reasoning would suggest. For taking each class as a whole we find that, with one exception, the higher the degree of the ametropia the greater is the extent of the convergence. From an average of 22·35° in the class whose lower meridian does not exceed 2 D. there is a steady increase up to 25·18° in that where the lower meridian ranges from 6 D. to 8 D. It is true that in the last class a great decrease appears in the average degree of convergence, but that class comprises no more than two individuals, one of them a case in many respects exceptional.

The same correspondence is seen in the first three subdivisions. In each of these, with a single break among the cases having astigmatism

TABLE XIV A.

Hypermetropia in lower meridian.	No astigmatism.		Astigmatism = ·5 D.		Astigmatism = 1·0 D.		Astigmatism over 1·0 D.		All cases together.	
	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.
Up to 2 D.	18	21·27°	9	20·88°	1	12·00°	3	36·66°	31	22·35°
2 D. to 4 D.	15	22·46	17	26·00	10	22·70	8	18·25	50	23·04
4 D. to 6 D.	9	25·00	8	23·87	5	25·00	4	18·00	26	23·57
6 D. to 8 D.	4	26·75	1	25·00	3	25·00	3	23·33	11	25·18
8 D. to 10 D.	2	17·50	—	—	—	—	—	—	2	17·50

TABLE XIV B (*isometropic cases omitted*).

Hypermetropia in lower meridian.	No astigmatism.		Astigmatism = ·5 D.		Astigmatism = 1·0 D.		Astigmatism over 1·0 D.		All cases together.	
	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.
Up to 2 D.	16	22·06°	8	19·12°	1	12·00°	5	30·00°	30	22·26°
2 D. to 4 D.	14	22·28	17	26·00	11	22·27	5	17·60	47	23·12
4 D. to 6 D.	9	25·00	4	28·50	3	25·00	3	15·66	19	24·26
6 D. to 8 D.	3	25·66	—	—	3	25·00	2	25·00	8	25·25

of ·5 D., the degree of convergence rises with the degree of the ametropia. It is only in the last subdivision in which the astigmatism exceeds 1 D. that no such correspondence can be traced. Here, however, we cannot be sure that the method of classification, though necessary in order to bring these cases into comparison with the rest, exhibits their relative position among themselves in regard to accommodative effort. For in some this might be adapted to the lower, in others to the higher meridian, so that its measure might differ considerably even in the case of eyes of very similar refractive condition. It is possible, therefore, that among these also, could they be arranged strictly according to the extent of the accommodative effort required of each in distant vision, the convergence might show itself more closely related to the ametropia than appears from the table. But whether that should be so or not, it seems to be sufficiently clear that in the great majority of cases the higher the ametropia of the fixing eye the greater is likely to be the deviation of the other.

Now in the case of the deviating eyes it cannot be possible—for the reason already given—that the refractive defect should influence the effort of accommodation after strabismus is once established. Yet the correspondence which we find between the extent of the convergence and the degree of the ametropia is closer than might have been expected. Table XV A shows for the

TABLE XV A.

Hypermetropia in lower meridian.	No astigmatism.		Astigmatism = ·5 D.		Astigmatism = 1·0 D.		Astigmatism over 1·0 D.		All cases together.	
	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.
Up to 2 D.	7	17·85°	5	28·00°	5	20·60°	9	22·44°	26	21·92°
2 D. to 4 D.	10	24·70	6	18·83	9	22·11	15	23·06	40	22·62
4 D. to 6 D.	9	24·66	13	25·30	7	25·00	9	21·88	38	24·28
6 D. to 8 D.	2	27·50	4	16·25	2	25·00	5	25·00	13	22·69
8 D. to 10 D.	2	17·50	1	35·00	—	—	—	—	3	23·33

TABLE XV B (*isometropic cases omitted*).

Hypermetropia in lower meridian.	No astigmatism.		Astigmatism = ·5 D.		Astigmatism = 1·0 D.		Astigmatism over 1·0 D.		All cases together.	
	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.	Number.	Average convergence.
Up to 2 D.	5	19·00°	4	26·25°	5	20·60°	9	22·44°	23	21·95°
2 D. to 4 D.	9	24·66	6	19·16	9	22·11	15	23·06	39	22·61
4 D. to 6 D.	9	24·66	10	26·10	5	25·00	8	21·50	32	24·37
6 D. to 8 D.	1	25·00	3	13·33	2	25·00	4	26·25	10	22·00
8 D. to 10 D.	—	—	1	35·00	—	—	—	—	1	35·00

deviating eyes the relations which were given in the last table for the fixing eyes. Taking all the cases together, the average degree of deviation is there seen to rise progressively throughout the first three classes, and these comprise 104 of the whole number. So also in the first and third subdivisions a similar increase of convergence is associated with increasing ametropia. On the whole, however, the relation does not appear to be nearly so intimate here as in the case of the fixing eyes.

But in order to make a stricter comparison between the two classes of eyes in this respect we ought to leave out of account, as factors common to either class, all those cases which were isometropic. Tables XIV B and XV B exhibit the results obtained by so doing. In regard to the fixing eyes we there find that as the ametropia increases, so the average degree of convergence rises in unbroken progression everywhere except among the cases having astigmatism of more than 1 D. But as to the deviating eyes, though the convergence increases with the ametropia among them also, and that in a fairly regular way, yet in two subdivisions only does the progression appear absolutely unbroken. We may conclude, therefore, not unreasonably, that in the former class this relation is an essential one, and that the extent of the deviation of the one eye is closely dependent upon the degree of the hypermetropia which provokes the accom-

modative efforts of the other; but that in the latter class it is accidental, and due only to the circumstance that the ametropia of the squinting eye is in most cases more or less proportionate to that of its fellow.

We have here, however, two difficulties to deal with. The first is the large proportion of cases in which only a low degree of hypermetropia was present. Taking those of the fixing eyes, forty-eight in number, which were not subject to astigmatism, we find that in eighteen the hypermetropia did not exceed 2 D. Of the fifteen in which it ranged from 2 D. to 4 D., six were hypermetropic to the extent of only 2·5 D. And among the astigmatic cases ten also measured only 2·5 D. in the higher meridian. There were therefore as many as twenty-eight cases—nearly one fourth of the whole number—in which the hypermetropia did not in any meridian rise beyond 2·5 D. Now it is usually stated that convergent strabismus is chiefly associated with hypermetropia of medium degree, for the reason, as regards the lower limit, that it is only when the refractive defect reaches a certain amount that clear vision can require an effort of accommodation so great as to entail excessive convergence. When hypermetropia of but low degree is present, the tendency to convergence which the accommodative effort brings with it is comparatively slight, and not more than the patient in his desire to maintain binocular vision is able to overcome. According

to this view, therefore, convergent strabismus ought to be rarely seen associated with a low degree of hypermetropia. How comes it, then, that in nearly 25 per cent. of a succession of unselected cases the hypermetropia of the fixing eyes was found not to exceed 2·5 D.? Even if we suppose that several of these patients were subject to hereditary influence, or to conditions specially favourable to the development of strabismus, it is not very likely that this can have been so with all of them. It seems to be a reasonable conclusion that we have here yet another indication that the potency of mere hypermetropia in the production of squint has been over-estimated, and that we must look further for some influence which avails itself, indeed, of the refractive defect, but is itself the actual efficient cause of the convergence. Such an influence, we can well understand, might be able to make itself felt even when the hypermetropia is of low degree, though acting more frequently and to greater effect in cases where a higher degree is present.

The second difficulty occurs in connection with the other end of the scale, where hypermetropia of considerable amount was found to exist in a relatively large number of cases. Of the fixing eyes, 13—a proportion of 10·83 per cent.—exhibited in their lower meridians hypermetropia of more than 6 D. Such figures seem to give little support to the common belief that convergent strabismus is rarely to be found associated with a high

degree of hypermetropic defect, and the matter therefore requires some consideration.

The force with which the fact assumed tells against the usual theory of this form of strabismus has been recognised, for it is obvious that, according to that theory, the higher the degree of hypermetropia the greater should be the accommodative effort, and the greater also should be the liability to abnormal convergence. Whilst, therefore, some of those who accept the fact as assured reject the theory altogether, the majority explain it by supposing that, in such circumstances, the effort required for clear vision is so great that the patient abandons it, and in so doing preserves his binocular vision.

This explanation, though supported by great authority, has its own difficulties. It is not easy to realise how any hypermetrope having a large range of accommodation at his disposal could give up entirely the attempt to improve his defective vision by employing at least some part of it. If he actually does so the whole of his hypermetropia should, on examination, be found to be manifest, for there can be none latent where there is no accommodation at work to conceal it And it ought, therefore, to be relatively common to find a complete absence of latent hypermetropia when the defect is of considerable extent, and that however young the patient may be. This is certainly not in agreement with ordinary experience. Supposing, however, that some

accommodation is used to improve the vision, how does it come about that such patients are better able than others to avoid the habit of strabismus? If it be true that they rarely squint, it must be either because their recti interni muscles are usually weak, or because the functions of accommodation and convergence are less closely associated in their case than in that of others.

But none of these explanations will be required if the fact which they are meant to explain cannot be substantiated. Now the fact assumed—that convergent strabismus is rare among cases of high hypermetropia—is not universally accepted, and it will be admitted that the evidence for its existence ought to be indisputable. The question is one not of absolute, but of relative frequency of occurrence. It may not be easy to find strabismus patients suffering from grave hypermetropic defect, simply because the total of those so affected is comparatively small. The greater, indeed, the ametropia, the fewer must be those who suffer from it. What has to be established is the occurrence of convergent strabismus in a less frequent proportion among the few whose defect is considerable than among the many in whom it is of only moderate extent. The question is one to be determined by the comparison of sufficient numbers of hypermetropes of either class, whether suffering from strabismus or not; and the figures before us, since they relate exclusively to cases in which squint had

developed, can throw no direct light upon it. But the comparative frequency with which the higher degrees of hypermetropia were found in these cases may fairly suggest a doubt whether the ordinary belief on this subject is, after all, well founded.*

Our inquiry, so far as it has gone, has resulted in showing that the extent of the deviation in convergent strabismus may be affected by circumstances of more than one kind, and the force which some of these exert we have been able to test by direct reference to figures. It is not suggested that those alone which have been so tested bear a part in the increase of the deformity. Other factors, such as hereditary tendency, insanitary surroundings, excessive strain, and the like, must, if they be present, exert some influence, but their effect can only be estimated in a very general fashion. It is, indeed, rather by the interaction of many factors than by the particular force of any one that the result is brought about.

In regard, for instance, to that very element of refraction which certainly plays such an important part in the production of strabismus, enough has

* The same doubt was expressed during the discussion on strabismus in the Ophthalmological Section of the British Medical Association at Dublin in 1887. In a valuable paper then read, Mr. Adams Frost gave statistics drawn from an examination of 200 cases. He found that the proportion of patients who, suffering from squint, exhibited hypermetropia of more than 6 D. was 10·1 per cent. ('British Medical Journal,' 1887, vol. ii, p. 663).

been said to indicate how far it is from being an all-sufficient cause of the condition. Yet one more illustration of its comparative inefficacy may be allowed. It might naturally be supposed that the more serious the defect the sooner would its influence be felt; in other words, that the greater the degree of hypermetropia the earlier would convergent strabismus be developed. But the supposition, however natural, is not supported by the facts before us. Neither the inequality between the eyes, nor the absolute refractive defect, appears to affect at all the period of life at which strabismus becomes established.

In regard to the former the relative distribution of cases according as they were found to be isometropic or the reverse should be a sufficient test, and this is shown by the following table.

TABLE XVI A.

Period of onset.	Isometropic.		Anisometropic.	
	Number.	Proportion.	Number.	Proportion.
		per cent.		per cent.
During 1st year . .	3	30·00	7	70·00
,, 2nd ,, . .	1	7·69	12	92·30
,, 3rd ,, . .	2	10·00	18	90·00
,, 4th ,, . .	2	8·00	23	92·00
,, 5th ,, . .	1	7·69	12	92·30
,, 6th ,, . .	1	9·09	10	90·90
,, 7th ,, . .	2	22·22	7	77·77
After 7th ,, . .	—	—	6	100·00

Anisometropia, so far from favouring the early onset of squint, was found least often among

those in whom the habit was developed the soonest. It may well be, of course, that so far as these cases were concerned this was more or less accidental, and that a fairer view of the matter would be obtained by extending the separate periods of onset from one year to two years. But the result of so doing as seen in Table XVI B is but slightly different, and it is at any rate clear that the mere difference in refrac-

TABLE XVI B.

Period of onset.	Isometropic.		Anisometropic.	
	Number.	Proportion.	Number.	Proportion.
		per cent.		per cent.
During 1st and 2nd years	4	17·39	19	82·60
„ 3rd „ 4th „	4	8·88	41	91·11
„ 5th „ 6th „	2	8·33	22	91·66
After 6th year . . .	2	13·33	13	86·66

tion between the two eyes has no influence in this respect.

Nor can we attribute any such influence to the absolute amount of hypermetropia which may exist. The difficulty in making comparison between several series of eyes in respect to their refractive condition has been already indicated, but we may here make use of a method which, though imperfect, will give results accurate enough for our purpose. This consists in working out the average degree of hypermetropia in both principal meridians of the eyes comprised in each

series, and then judging how these averages compare with one another.

TABLE XVII A.

Period of onset.	Number.	Average degree of hypermetropia in the fixing eyes.		Average degree of hypermetropia in the deviating eyes.	
		Lower meridian.	Higher meridian.	Lower meridian.	Higher meridian.
During 1st year	10	3·65 D.	5·25 D.	4·25 D.	5·50 D.
,, 2nd ,,	13	3·00 D.	3·53 D.	3·84 D.	4·53 D.
,, 3rd ,,	19	4·39 D.	4·84 D.	4·84 D.	5·65 D.
,, 4th ,,	25	3·30 D.	3·96 D.	3·64 D.	5·04 D.
,, 5th ,,	13	3·73 D.	4·38 D.	4·30 D.	5·15 D.
,, 6th ,,	10	3·55 D.	4·00 D.	3·60 D.	4·35 D.
,, 7th ,,	9	4·05 D.	4·66 D.	3·88 D.	5·05 D.
After 7th ,,	6	3·91 D.	4·00 D.	3·75 D.	4·58 D.

The most remarkable feature in this table is the singular uniformity which overspreads it. Whatever series be taken, the average degree of hypermetropia in any given meridian does not differ by as much as 2 D. from that found in any other series, and usually the difference is much less. Neither is there any kind of gradation in the averages, upwards or downwards, from the first series to the last.

If exception be taken to results thus obtained, there is yet another way of examining the matter. In Table VII it was shown that forty-eight of the fixing and thirty of the deviating eyes were subject to simple hypermetropia only. The period of onset was ascertained in forty-one of

the former and twenty-four of the latter class. These instances should be enough to show us what influence, if any, was exercised by hypermetropia, uncomplicated by astigmatism, in the early development of the strabismus.

TABLE XVII B.

Period of onset.	Fixing eyes.		Deviating eyes.	
	Number.	Average degree of hypermetropia.	Number.	Average degree of hypermetropia.
During 1st year .	3	2·33 D.	3	3·18 D.
,, 2nd ,, .	7	2·14 D.	5	3·70 D.
,, 3rd ,, .	9	4·56 D.	4	5·12 D.
,, 4th ,, .	9	2·84 D.	3	2·66 D.
,, 5th ,, .	5	3·50 D.	4	4·62 D.
,, 6th ,, .	3	4·16 D.	1	4·00 D.
,, 7th ,, .	3	1·83 D.	2	2·00 D.
After 7th ,, .	2	5·00 D.	2	4·50 D.

The figures given in Table XVII B, however, make it impossible for us to suppose that in these cases the degree of the refractive defect had anything to do with the time at which the squint appeared; for they show that almost the lowest average degree of hypermetropia was to be found among those who developed the affection during the first two years of life,—exactly the reverse, that is, of what the hypothesis demands. But the irregularity with which the average rises and falls throughout the successive groups is alone enough to make the supposition untenable. We conclude, therefore, that the time at which con-

vergent strabismus first manifests itself is determined by something else than the degree of hypermetropia that may be present. This defect of refraction, present from birth, destined to be at all times a hindrance to vision, and ready, under certain circumstances and special influences, to be the chief agent in producing the excessive convergence which we call squint, is not itself the primary cause thereof.

In regard, then, to this question of hypermetropia, our examination of the cases before us leads to the following conclusions.

The defect is almost universally present in monolateral convergent strabismus.

The squinting eyes as a class are inferior to the fixing eyes in that—

i. Simple hypermetropia is less common among them, and the lower degrees thereof occur less often;

ii. Astigmatism is not only more common, but the higher degrees thereof occur more often among them.

The hypermetropia may, however, attain as high a degree in the one class as in the other.

In individuals the squinting eye is not, as usually assumed, necessarily inferior to its fellow, since—

i. The fixing eye may sometimes, as regards refraction, be rather the worse of the two;

ii. In one seventh of all the cases, monolateral and alternating, no refractive inequality at all could be found.

Anisometropia, therefore, great as its influence may be, does not play the important part sometimes assigned to it :

i. Its presence, as just stated, is not necessary for the development of squint ;

ii. Nor does it specially conduce to an early onset thereof ;

iii. Its amount has no relation to the degree of convergence that may be attained.

The actual hypermetropia, on the other hand, is not only the almost necessary agent in producing convergent strabismus, in the causation of which it may be regarded as the dominant factor, but—

i. Its degree appears to bear direct relation to the extent of the deformity produced ;

ii. This relation is chiefly marked in connection with the fixing eyes, but is traceable also in the case of the deviating eyes ;

iii. There is besides good reason for doubting the soundness of the usual belief, that convergent strabismus is not so common relatively among hypermetropes of high as among those of medium degree.

Nevertheless it is possible to overrate its importance, since—

i. In nearly one fourth of the cases it did not, in the fixing eyes, exceed 2·5 dioptres ;

ii. Its degree appears to have no influence upon the time of onset of the squint.

Something, therefore, is required beyond the mere presence of this defect of refraction to bring about convergent strabismus.

SECTION IV.

THE VISION IN MONOLATERAL CONVERGENT STRABISMUS.

We have now to consider that which is the most interesting of the phenomena associated with strabismus, as it is certainly that on which the sharpest differences of opinion exist—the defective visual power of the squinting eye. With this, of course, is involved the question of the absence of diplopia in squinting patients.

From the great majority of such patients no complaint that objects are seen double is ever heard, in remarkable contrast to what happens when the relations of the eyes to each other have been disturbed by paralysis. And since the vision of squinting eyes is usually found to be more or less seriously depreciated, the freedom from diplopia is commonly explained as being due to this circumstance, the visual act having become the function of one eye only, and one set of retinal impressions alone being perceived by the brain. So far, indeed, there is, and can be, little difference of opinion ; for in whatever way the absence of diplopia may be explained in other cases where,

as in alternating strabismus, the vision of the two eyes is nearly or quite alike, the fact of one eye seeing very imperfectly must exclude the possibility of its perceptions interfering with those of the other.

But as to how it comes about that the vision of the squinting eye should be thus inferior to that of its fellow there is sharp divergence. The most common view is that binocular vision was originally present, and that the onset of squint gave rise to diplopia, but that to escape the consequent annoyance the images formed on the retina of the deviating eye were ignored or "suppressed," this mental suppression by long continuance leading in the end to actual loss of the visual capacity of the eye. This theory, though it has obtained wide acceptance, and is supported by high authority,* has nevertheless but a slender foundation to rest upon. There is brought forward in its favour in the first place the undoubted fact that those in whom strabismus arises at a later age than usual do often complain of diplopia at first, and that the trouble after a time ceases. It is also now generally admitted that in many, perhaps most, patients with fully developed squint, diplopia can be artificially evoked. Further, it is maintained, on the one hand, that in individual cases progressive deterioration has been observed; and on the other, that improve-

* It originated apparently with von Graefe, and still remains the ordinary text-book explanation of the amblyopia of squint.

ment can be effected by exclusive use of the faulty eye.

Now the existence of double vision, whether arising spontaneously or artificially produced, shows that binocular vision formerly existed. Nor is there good reason to doubt that it is by a mental suppression of one image that strabismus patients succeed in making latent from their own consciousness a diplopia which may have been manifest enough at first. But between such voluntary suppression of retinal images and permanent incapacity to recognise them, there is a wide interval which cannot easily be bridged. The absence of diplopia does not necessarily imply feeble vision in one eye, often as it may be associated therewith. And whilst the direct evidence in favour of progressive deterioration is scanty and unsatisfactory, there is to be set against it the well-known fact that an eye may be excluded from vision for many years without losing its visual capacity. The possibility of some improvement in the vision of a squinting eye may be admitted, but it can be explained more easily than by supposing that there is partial restoration of a faculty that has been lost.

To meet these difficulties the alternative theory has been framed, that the defective vision of the squinting eye is not acquired, but congenital; that instead of being a consequence of strabismus it is a chief factor in producing that condition, and neither made worse by its continuance nor

susceptible of improvement by its removal.* Two principal objections are offered to this theory: the one, that congenital monocular defect of vision is not to be found apart from strabismus; the other, that with such a condition of things binocular vision can never have been accomplished, though the facts already alluded to indicate that in most cases it must at one time have existed. But if these objections can be satisfied there should be little difficulty in accepting a theory which not only offers a solution of many of the phenomena connected with strabismus, but goes far towards explaining its origin.

The recognition, indeed, of the important part which a primary defect of vision in one eye may play in helping to produce strabismus has given rise to yet a third view, according to which part of the defect found in squint is regarded as congenital, the remainder being the result of disuse.† The distinction between the two elements would thus be marked in any particular case by the degree of improvement that could be brought about through exclusive practice of the defective eye. So much of the deficiency as might be remedied in this way should, on this view, be con-

* The chief exponent of this theory at the present time is, of course, Professor Schweigger, whose monograph on 'Squint' is well known (English translation, London, 1887).

† See Fuchs, 'Lehrbuch der Augenheilkunde,' 2nd edit., 1891, p. 626.

sidered as due to disuse, whatever might be left as congenital. The possibility, therefore, of a congenital lack of visual capacity in one eye is admitted by those who adopt this explanation; how far their belief in a further partial loss of vision from voluntary suppression may be tenable must be decided by the same considerations that apply to a supposed total loss from the same cause.

In discussing these various theories it is necessary to have a clear idea as to what is implied by the term—amblyopia—commonly used to express the visual defect; to ascertain what relation it may bear to the refraction; and to inquire how far and in what degrees it prevails among strabismus patients. Equally essential is it to discover by such methods as may be open to us whether or no the effect is a progressive one. Without some definite knowledge on these points any sure judgment on its ætiology must be impossible.

The materials for these inquiries are less abundant than for those we have hitherto been engaged in, because vision is a sense which can only be examined subjectively, and out of a number of patients of tender years there must of necessity be many to whom the ordinary tests of vision cannot be applied, and from whom, therefore, no results can be obtained. There is a further disadvantage in that we can have no direct

means of ascertaining when the defect of vision first existed. Often, indeed, the patient is quite unconscious of any such defect up to the time of first seeking treatment for the associated deformity. The period of life when advice is most often sought for the first time is from the end of the fifth to the end of the tenth year, when convergence has in general been long established.* The vision of the deviating eye in these cases is usually defective, but whether the defect was present before the convergence appeared, or only followed its establishment, we cannot directly tell. On this, the chief problem which strabismus presents to us, our conclusions must be drawn from a consideration of the whole of the circumstances.

What, then, is to be understood when we speak of this defect, or—to use the common term—this amblyopia? Now there are not a few strabismus patients in whom the sense of vision in the deviating eye is very far from being entirely absent. They can, even without correction of the refractive defect, read some of the ordinary type used in testing distant vision. But if careful correction be made, a certain number, though not all of these will show some degree of improvement. Of the cases specially examined in reference to this point, in all of which the vision of the fixing eye attained the normal

* See Table II above, page 10.

standard, there was distinct improvement after correction in as many as 40·90 per cent., whilst in the remaining 59·10 per cent. no such improvement could be effected. In squinting eyes, therefore, the visual defect may be composed of two elements,—the one being accidental and dependent entirely on faulty optical conditions, correction of which causes its disappearance; the other essential and permanent. It is to the latter alone that the term amblyopia properly belongs, and the amblyopia of strabismus may be described as that defect of vision in the deviating eye which remains after full correction of the refractive defect. It is in this sense that the expression is used throughout these pages.*

By what standard is this amblyopia to be measured? A little consideration will convince us that whatever degree it may attain, the defect must be regarded less as an absolute than a relative one. Let us take the case of two patients, neither of them able with his squinting eye to see more, after correction of refractive errors,

* The possibility of improving the vision of squinting eyes by correction of refractive error was tested by Messrs. Lang and Barrett. Out of a total of 78 instances such improvement was obtained in 37—a proportion of 47·43 per cent.; the remaining 41, constituting 52·56 per cent. of the number, remained unaffected. Quite two fifths, therefore, of the eyes subject to convergent squint appear capable of improvement merely by the proper adaptation of glasses—a fact which cannot be neglected in estimating the extent of their amblyopia ('Roy. Lond. Ophth. Hosp. Reports,' vol. xii, p. 135).

than $\frac{6}{24}$ Snellen, but of whom one can with his fixing eye, after correction, read $\frac{6}{6}$ whilst the other can get no further than $\frac{6}{12}$. Measured by an absolute standard the deviating eye in each is depreciated to exactly the same extent, and possesses only one fourth of ordinary normal vision. But if each be compared with its fellow we get a very different result. In the one case the fixing eye can read $\frac{6}{6}$ Snellen, and the deviating eye has, therefore, to be judged by a standard equal to that of normal vision. Hence the relative and the absolute depreciation are in this instance identical, and the squinting eye, by either method of estimation, lacks three fourths of the amount of vision that it ought to possess. In the other case, however, the fixing eye is itself deficient. It can read only $\frac{6}{12}$ Snellen, and its power of vision, therefore, is only half that of a normal eye. Compared with this, its depreciated fellow, the squinting eye, which reads $\frac{6}{24}$, has lost no more than one half of the vision that it ought to have, and hence its relative position is distinctly better than if the fixing eye were normal. The vision in both is defective, but that very fact puts them more nearly on a level with each other. It follows that the term amblyopia, when used in connection with strabismus, ought to bear a meaning rather relative than absolute, and should be defined as the defect of vision existing in a squinting eye as compared with its fellow, after correction of all refractive errors in both.

It would of course be highly convenient could we take normal vision as the measure by which to estimate the amblyopia of all squinting eyes, but it is only when their fellow fixing eyes themselves attain it that such a standard can be employed. Often enough this is not the case, and we cannot fairly set up for a squinting eye any higher standard than that actually reached by the fixing eye, however much depreciated that may happen to be. We are obliged, therefore, to put aside the wish for one absolute uniform measure, and to remain content with the comparison of one eye with the other in each individual case. By a method to be described hereafter the relative depreciation of vision in any number of squinting eyes can be tabulated and compared together in spite of variations in the power of vision in the corresponding fixing eyes.

It has been assumed so far that considerable differences exist among squinting eyes in respect of their powers of vision. That this must be the case would doubtless be admitted by all, but it is a fact which it is necessary to demonstrate, not only as being highly important in itself, but as one that is liable to be somewhat overlooked. So many squinting eyes fail to respond even to the lowest tests of distant vision that there is a natural tendency to place the whole class under the ban of "amblyopia," and to neglect any thorough examination of their visual capacity.

And hence a squinting eye which can see fairly well is apt to be looked on as something exceptional, and probably destined also, sooner or later, to the loss of all useful vision. Of our 120 cases there were seventy-five whose vision could be properly tested. It will be convenient to give in the first place the varying degrees of vision attained by the fixing eyes. These are shown in the following table.

TABLE XVIII.*

Vision in fixing eye.	Number.	Proportion.
$\frac{6}{6}$ Snellen	42	56·00 per cent.
$\frac{6}{9}$,,	16	21·33 ,,
$\frac{6}{12}$,,	7	9·33 ,,
$\frac{6}{18}$,,	7	9·33 ,,
$\frac{6}{24}$,,	3	4·00 ,,

It will be noted that apart from refractive errors the vision of these eyes reached in general a satisfactory level. In less than one fourth of them was it seriously depreciated. Among the deviating eyes a very different state of things prevailed. The results obtained from examination of these are gathered in Table XIX, in which the cases are classified according to the acuteness of vision in the fixing eyes in order to avoid the fallacy of comparing together organs which—as already explained—cannot properly be judged by

* In this and subsequent tables the vision given is that found after full correction of all refractive errors.

Table XIX.

Vision in deviating eye.	Vision in fixing eye = $\frac{6}{6}$.		Vision in fixing eye = $\frac{6}{9}$.		Vision in fixing eye = $\frac{6}{12}$.		Vision in fixing eye = $\frac{6}{18}$.		Vision in fixing eye = $\frac{6}{24}$.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
$\frac{6}{6}$	4	9·52 per cent.								
$\frac{6}{9}$	6	14·28 ,,	2	12·50 per cent.						
$\frac{6}{12}$	2	4·76 ,,	1	6·25 ,,						
$\frac{6}{18}$	11	26·19 ,,	3	18·75 ,,	—	—	1	14·28 per cent.		
$\frac{6}{24}$	5	11·90 ,,	1	6·25 ,,	—	—	2	28·56 ,,	1	33·33 per cent.
$\frac{6}{36}$	2	4·76 ,,	1	6·25 ,,						
$\frac{6}{60}$	3	7·14 ,,	2	12·50 ,,	1	14·28 per cent.	1	14·28 ,,	1	33·33 ,,
$<\frac{6}{60}$	9	21·42 ,,	6	37·50 ,,	6	85·71 ,,	3	42·84 ,,	1	33·33 ,,

the same standard. The fact of variation is here amply demonstrated. For though there was on the whole a preponderance of cases showing less than one tenth of normal vision—some of them, it may be added, not possessing even the power of fixation,—yet there was to be found in nearly every class at least one instance of absolute equality of vision as between the deviating and the fixing eye. And between these extremes every possible degree of vision was exemplified. If a formula, therefore, be required to express this state of things, it may be found in the statement that the amblyopia of strabismus may vary from zero to infinity.

In endeavouring to follow up our investigations on this branch of the subject it would be so obviously convenient to avoid having several classes of cases to deal with, that an attempt to treat them all as a single group needs no justification, provided that no fallacy be thereby introduced. The method here employed rests on the principle, already sufficiently insisted on, that the amblyopia of a squinting eye must be considered as a relative rather than an absolute defect. For our present purpose, therefore, we place all the fixing eyes on one level. It matters nothing whether these see well or badly ; each of them is for its fellow the standard of perfection, and if we can give them all a common value, that value may stand as the common measure of all the squinting eyes. For example, one patient reads

with his fixing eye $\frac{6}{6}$ Snellen, and with his deviating eye $\frac{6}{18}$. The visual power of the latter is only one third that of the former, the relative amblyopia, that is, amounts to two thirds, or 66 per cent. But a second patient, who with his fixing eye reads $\frac{6}{12}$, is able with the other eye to read $\frac{6}{36}$. The relative depreciation is here exactly the same as before, for the one eye is again only one third as good as its fellow. The amblyopia of the patient whose deviating eye can read no more than $\frac{6}{36}$ is relatively no greater than that of the other, who could with his squinting eye read $\frac{6}{12}$. We require, then, a series of symbols to express, in the first place, the assumed equality of vision in the fixing eyes, and in the second, the varying degrees by which that of the deviating eyes may fall short of that uniform standard. Such a series may be devised with no great difficulty.

Unity, as being the simplest possible, is the value which we naturally give to the fixing eyes. As the next step we arrange in tabular form the various degrees of relative amblyopia, expressing them as decimal fractions of unity. Table XX shows the easy gradation of these fractions from zero upwards, corresponding to the gradual increase of the amblyopia from nothing to infinity. It shows also, by the frequent occurrence of similar fractions in the various classes, how often the same degree of relative amblyopia may be represented by very different degrees in the actual acuteness

Table XX.

Vision in fixing eyes.	Relative amblyopia in deviating eyes.							
	V. = $\frac{6}{6}$.	V. = $\frac{6}{9}$.	V. = $\frac{6}{12}$.	V. = $\frac{6}{18}$.	V. = $\frac{6}{24}$.	V. = $\frac{6}{36}$.	V. = $\frac{6}{60}$.	V. = $<\frac{6}{60}$.
$\frac{6}{6}$	0	·33	·50	·66	·75	·83	·90	1·00
$\frac{6}{9}$	—	0	·25	·50	·63	·75	·85	1·00
$\frac{6}{12}$	—	—	0	·33	·50	·66	·80	1·00
$\frac{6}{18}$	—	—	—	0	·25	·50	·70	1·00
$\frac{6}{24}$	—	—	—	—	0	·33	·60	1·00
$\frac{6}{36}$	—	—	—	—	—	0	·40	1·00
$\frac{6}{60}$	—	—	—	—	—	—	0	1·00

of vision. Even when not absolutely alike, some of the fractions are so nearly so as to be practically identical. A variation in relative amblyopia indicated by the difference between such quantities as ·80 and ·83, or even such as ·60 and ·66, is not worth insisting on, and consequently no appreciable error will be introduced if the fractions be carried no further than a single place of decimals. By so doing we shall reduce their number from thirteen to nine, and be able to place them in a regular series from ·2 to ·9. Such a series would of itself serve the purpose of a scale of measurement for relative amblyopia; but a yet simpler one may be obtained if we discard the form of fractions altogether, and after removing the decimal points use the resulting integers as the symbols we require. At the one end of the scale the figure 1 will serve as the symbol of equality of vision; at the other the number 10 will conveniently indicate absolute

relative amblyopia. The following table will show the succession of symbols and the degree of relative amblyopia which each of them represents.

Table XXI.

Symbol.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Degree of relative amblyopia	0	·25	·33	·40	·50	·60 to ·66	·70 to ·75	·80 to ·85	·90	∞

It will be useful to add a further table showing the actual acuteness of vision which these symbols imply according to the standard of vision attained in the fixing eye.

Table XXII.

Vision in fixing eye.	Vision represented by the symbols of relative amblyopia.									
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
$\frac{6}{6}$	$\frac{6}{6}$	—	$\frac{6}{9}$	—	$\frac{6}{12}$	$\frac{6}{18}$	$\frac{6}{24}$	$\frac{6}{36}$	$\frac{6}{60}$	$< \frac{6}{60}$
$\frac{6}{9}$	$\frac{6}{9}$	$\frac{6}{12}$	—	—	$\frac{6}{18}$	$\frac{6}{24}$	$\frac{6}{36}$	$\frac{6}{60}$	—	$< \frac{6}{60}$
$\frac{6}{12}$	$\frac{6}{12}$	—	$\frac{6}{18}$	—	$\frac{6}{24}$	$\frac{6}{36}$	—	$\frac{6}{60}$	—	$< \frac{6}{60}$
$\frac{6}{18}$	$\frac{6}{18}$	$\frac{6}{24}$	—	—	$\frac{6}{36}$	—	$\frac{6}{60}$	—	—	$< \frac{6}{60}$
$\frac{6}{24}$	$\frac{6}{24}$	—	$\frac{6}{36}$	—	—	$\frac{6}{60}$	—	—	—	$< \frac{6}{60}$
$\frac{6}{36}$	$\frac{6}{36}$	—	—	$\frac{6}{60}$	—	—	—	—	—	$< \frac{6}{60}$
$\frac{6}{60}$	$\frac{6}{60}$	—	—	—	—	—	—	—	—	$< \frac{6}{60}$

We are now in a position to show, as in Table XXIII, the distribution of relative amblyopia throughout our series of seventy-five cases. The essential points to notice therein are

two; the first being the presence of extreme relative amblyopia in just one third of the cases, the second the absence in more than one tenth of their number of any relative amblyopia whatever.

TABLE XXIII.

Symbol of relative amblyopia.	Actual defect.	Number.	Proportion.
1	0	8	10·66 per cent.
2	·25	3	4·00 ,,
3	·33	6	8·00 ,,
4	·40	0	—
5	·50	5	6·66 ,,
6	·60—·66	13	17·33 ,,
7	·70—·75	7	9·33 ,,
8	·80—·85	5	6·66 ,,
9	·90	3	4·00 ,,
10	∞	25	33·33 ,,

It is desirable to know, however, whether similar proportions in respect to these two extremes of relative visual acuteness are maintained among all classes of cases. To ascertain this we have only to arrange the five classes of cases we have to deal with, not, as in Table XIX, according to the actual vision which the deviating eyes possessed, but according to the degree of relative amblyopia they presented. This has been done in Table XXIV A, and we may for purposes of comparison separate, as in Table XXIV B, the first two classes in which the vision of the fixing eye did not fall below $\frac{6}{9}$ from the last three in which it ranged from $\frac{6}{12}$ to $\frac{6}{24}$. The

TABLE XXIV A.

Symbol of relative amblyopia.	Vision in fixing eye = $\frac{6}{6}$.		Vision in fixing eye = $\frac{6}{9}$.		Vision in fixing eye = $\frac{6}{12}$.		Vision in fixing eye = $\frac{6}{18}$.		Vision in fixing eye = $\frac{6}{24}$.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
1	4	9·52 per cent.	2	12·50 per cent.	—	—	1	14·28 per cent.	1	33·33 per cent.
2	—	—	1	6·25 ,,	—	—	2	28·56 ,,		
3	6	14·28 per cent.								
4										
5	2	4·76 ,,	3	18·75 ,,						
6	11	26·19	1	6·25 ,,	—	—	—	—	1	33·33 ,,
7	5	11·90 ,,	1	6·25 ,,	—	—	1	14·28 per cent.		
8	2	4·76 ,,	2	12·50 ,,	1	14·28 per cent.				
9	3	7·14 ,,								
10	9	21·42 ,,	6	37·50 ,,	6	85·71 ,,	3	42·84 ,,	1	33·33 ,,

TABLE XXIV B.

Symbol of relative amblyopia.	Vision in fixing eye $\frac{6}{6}$ to $\frac{6}{9}$.		Vision in fixing eye $\frac{6}{12}$ to $\frac{6}{24}$.	
	Number.	Proportion.	Number.	Proportion.
1	6	10·34 per cent.	2	11·76 per cent.
2	1	1·72 ,,	2	11·76 ,,
3	6	10·34 ,,	0	—
4				
5	5	8·62 ,,	0	—
6	12	20·68 ,,	1	5·88 per cent.
7	6	10·34 ,,	1	5·88 ,,
8	4	6·89 ,,	1	5·88 ,,
9	3	5·17 ,,	0	—
10	15	25·86 ,,	10	58·82 per cent.

former comprised fifty-eight cases, the latter seventeen. Among the fifty-eight cases there were to be found six, a proportion of 10·34 per cent., that possessed equality of vision; of the seventeen there were two, or 11·76 per cent., in the same advantageous position. In this respect, then, but little difference prevailed, and we may conclude that whatever degree of actual vision may be attained by the fixing eye, at least 10 per cent. of all cases of convergent strabismus will show no relative amblyopia whatever. But as to the other extreme of relative vision considerable difference was manifested between the two sets of cases. Out of the fifty-eight in whose fixing eyes the vision was normal or nearly so only fifteen showed absolute relative amblyopia in the deviating eyes. These fifteen formed a proportion of 25·86 per cent. On the other hand, among the seventeen cases with depreciated

vision in the fixing eyes absolute relative amblyopia was found in as many as ten, a proportion of 58·82 per cent; this condition, that is to say, occurred twice as often among the latter as among the former. Unless these results are to be taken as purely accidental—and they are drawn from a fair number of cases—they justify us in holding that as a general rule the worst degrees of amblyopia in deviating eyes are chiefly to be found among such cases as show marked depreciation of vision in the fixing eyes. The better the vision of these latter, the less likely is that of the former to be hopelessly bad.

Now the fact of such an association existing between the visual capacities of the two eyes has an important bearing on the question before us. When, after everything has been done to correct refractive error, the vision in both eyes of a patient is found to be defective, it is clear that the common defect must be referred to a common cause. This—local lesions of course being excluded—can be nothing else than a congenital inability to perform properly the act of vision. And it is difficult to see why one eye should not suffer in a greater degree from this inability than the other, unless we are to suppose that the congenital deficiency must always be equally distributed between the two. If, however, the possibility of such a congenital inequality between the eyes be admitted, there is no reason why it should not vary in degree in different indi-

viduals from zero to infinity. The necessity for supposing the amblyopia of squint to be the result of disuse would thus disappear.

It may be maintained, nevertheless, that whilst congenital amblyopia may exist, there can be no great inequality in this respect between the two eyes. If this view be taken, it would follow that when the vision of both eyes happens to be defective, so much only of the deficiency as is common to both can be admitted to be congenital, any excess of amblyopia in the squinting eye being due to disuse. And in those cases where the vision of the fixing eye is normal there would be no reason to suppose any part of the defect in the deviating eye to be other than acquired. It is incumbent, however, on those who attribute such serious results to a habit of suppression to explain how it comes about that one patient in every ten of those suffering from constant strabismus shows no relative amblyopia whatever. So far from any being supposed to be exempt from the habit, it is usually assumed that all must sooner or later succumb to it and incur its consequences, so that amblyopia should, on this assumption, be altogether absent only when there has not been sufficient time since the onset of the squint for deterioration of vision to take place.

It is essential, then, to make out whether the degree of amblyopia in a squinting eye bears any relation to the length of time which may have

elapsed since the strabismus first appeared. In no other way, indeed, can we draw any inference as to whether the vision has changed for the worse, since we can know nothing of the visual capacity of such an eye before it began to squint.

Of the seventy-five cases now before us, it was possible to learn in sixty-two the actual time that the squint had existed before treatment was sought. It has already been pointed out, however, that owing to the early onset of convergent strabismus there is generally some proportion between its duration and the age of the patient. And since the age of all the present examples was noted on their first appearance, when also the best possible vision of the faulty eyes was ascertained, some reasonable conclusions may be drawn from a comparison of these two series of facts with one another.

TABLE XXV.

Symbol of amblyopia.	Actual defect.	Number.	Average age.	Lowest age.	Highest age.
1	0	8	9·12 years	6 years	16 years
2	·25	3	10·00 ,,	8 ,,	12 ,,
3	·33	6	16·00 ,,	12 ,,	25 ,,
4	·40				
5	·50	5	8·00 ,,	5 ,,	10 ,,
6	·60—·66	13	10·07 ,,	6 ,,	16 ,,
7	·70—·75	7	17·00 ,,	11 ,,	32 ,,
8	·80—·85	5	14·20 ,,	6 ,,	18 ,,
9	·90	3	15·33 ,,	8 ,,	21 ,,
10	∞	25	11·20 ,,	5 ,,	22 ,,

In Table XXV the cases have been arranged

according to the degree of relative amblyopia in the squinting eyes. In the first column are placed the symbols proposed to represent the successive degrees of this condition, and in the second is shown the actual extent of the defect to which each of them corresponds, expressed in decimal fractions of unity. The third column gives the number of patients subject to each degree of relative visual defect; the fourth the average age of each group; whilst in the fifth and sixth are exhibited the extremes of age found in the various groups. It will be seen that there is little here to favour the supposition that the age is likely to be less advanced among those presenting but a low degree of relative amblyopia, or more advanced in those suffering from the highest degrees thereof. The average of eight patients in whom the deviating eye enjoyed as good vision as the fixing eye was 9·12 years; that of twenty-five in whom the squinting eye possessed no useful vision at all amounted to 11·20 years—an increase certainly, but by no means so great as might have been looked for. Moreover the lowest average age, eight years, was found among those in whom the one eye saw only half as well as the other; the highest, seventeen years, occurred among those whose deviating eyes still retained one fourth of the visual power possessed by their fixing eyes. Similar results are reached by a study of the extremes of age found in each group. Taking the

age, then, of these patients as a rough measure of the time during which they had been subject to convergent strabismus, it does not appear that it bore any special relation to the extent of the visual defect in their deviating eyes. In other words, the sight of the squinting eyes was not made worse by the longer duration of the squint.*

Without, however, laying undue stress on the element of age, which is not invariably a guide to the time that the strabismus has existed, let us examine the matter by means of those cases in which the actual duration of the squint could be ascertained. There were, as has been said, sixty-two such, and the results obtained from them are set forth in Table XXVI, which has been constructed on the same plan as the last, by sub-

TABLE XXVI.

Symbol of amblyopia.	Actual defect.	Number.	Average duration.	Shortest duration.	Longest duration.
1	0	5	4·43 years	·16 years	8 years.
2	·25	2	5·50 ,,	5·00 ,,	6 ,,
3	·33	4	12·50 ,,	9·00 ,,	22 ,,
4	·40				
5	·50	5	3·51 ,,	·58 ,,	7 ,,
6	·60—·66	13	5·38 ,,	1·00 ,,	12 ,,
7	·70—·75	6	10·70 ,,	·25 ,,	25 ,,
8	·80—·85	4	9·50 ,,	1·00 ,,	16 ,,
9	·90	3	12·00 ,,	6·00 ,,	18 ,,
10	∞	20	6·95 ,,	·02 ,,	18 ,,

* Mr. Adams Frost found no appreciable difference between the average age of amblyopic (V. less than $\frac{6}{18}$) and non-amblyopic cases ('British Medical Journal,' 1887, vol. ii, p. 663).

stituting the figures indicating the duration of the complaint for those relating to the age of the patients. (Table XXVI.)

In the first group of five individuals in whom the vision of the eyes was equal the average previous duration of the squint was 4·43 years; in the last group, comprising twenty whose deviating eyes suffered from absolute amblyopia, it amounted to 6·59 years,—again an increase, but less remarkable than might have been expected. Nor can the difference be considered important when we note further that it is not in the former that the shortest, nor in the latter that the longest average duration of the series is to be found. There is, in fact, a complete absence of any such gradual advance in average duration from one end of the table to the other as might suggest an association between the degree of the visual defect and the length of time the strabismus has lasted. And if this be so in regard to the cases when taken together, it is still more manifest on examination of special instances. There are, no doubt, cases not unfrequently met with in ordinary practice showing low degrees of amblyopia associated with a brief existence of squint; there are many more in which absolute amblyopia is an accompaniment of old-standing convergence. Our present series will itself furnish such, but even if they stood by themselves they would not prove that the vision of squinting eyes becomes worse by lapse of time.

Only if the sight in the former class were subsequently found to have deteriorated, or if that of the latter were proved to have been better at an earlier period, could the proposition be entertained. And if examples of the reverse conditions occur with any frequency,—if, that is, we find, on the one hand, eyes which have squinted for several years still in possession of good vision; or, on the other, eyes which have only recently succumbed to strabismus quite unable to see properly, it must entirely fall to the ground. Now, on looking at the last two columns of Table XXVI—those showing the extreme periods of duration found in the several groups of cases—it will be noticed that an instance occurred in the first group where, with equal vision in the two eyes, squint had been present for as many as eight years; whilst in the last group was a patient who, having absolute amblyopia in the deviating eye, was believed to have suffered from strabismus for no longer a period than ten days. Even if, in this last case, a considerable error is to be allowed for in the statement of a parent whose observation may have been at fault, we have the fact that the child was only five years old, and therefore unlikely to have been squinting for any great length of time. Yet the extreme of bad vision was found in her. Nor should this patient be regarded as an isolated example, for in nearly all the groups in which the relative amblyopia attained a high degree cases occurred in which

the duration of the strabismus had not extended beyond twelve months; and, conversely, the long duration of the squint in the case referred to as showing no relative amblyopia can be paralleled by others both in its own group and in those other groups where the vision was but slightly depreciated.

With what degree of frequency, then, do such cases as these of either kind occur? Are they only exceptional, or do they form a substantial proportion among squinting patients? The question can only be answered by finding out the ratio in which they stand to the total number of cases in the groups to which they belong. Now, in the first group, where the vision of the eyes was equal, we find that three out of the five cases, being a proportion of 60 per cent., had suffered from squint for more than five years—a period within which the habit of suppression, if it has any deteriorating effect upon the sight, ought certainly to have shown its influence. On the other hand, in the last six groups, comprising fifty-one cases in which the relative amblyopia amounted to a deficiency of one half or more, there were eleven, or 21·56 per cent., whose squint had existed for less than three years, and of these four occurred in the last group where absolute amblyopia prevailed; that is to say, of those who suffered from a serious deficiency of vision amounting even to absolute amblyopia in the squinting eye, one fifth had been subject to

strabismus for a comparatively short time. It is easy to say that these latter may be simply instances of an early yielding to the influence of disuse; it is difficult to accept such an explanation in the face of those others whose resistance to the same influence was so complete.

For the foregoing reasons, therefore, it must be held that no relation exists between the degree of relative amblyopia and the time that may have elapsed since the first appearance of the squint. Without discussing at present how far the habit of suppression of retinal images may be developed, it is sufficient to note that its long continuance does not appear to result in loss of visual capacity to the eye in which it is practised. And if the defect of vision in a squinting eye be not an acquired defect, it must have its origin in congenital conditions.

Is it possible—we may now inquire—to trace any connection between the state of the refraction and the state of the vision in squinting eyes? We know that in the majority of cases such eyes are distinctly worse as regards refraction than their fellow fixing eyes,—a certain number, however, showing no deficiency in this respect. On the other hand, whilst we find the vision in most deviating eyes to be worse than that in the fixing eyes, in some cases no such depreciation exists. What, then, is the nature of the relation between these two series of facts? In other words, is the

feeble vision in any degree dependent on the defective refraction, or is it merely associated therewith?

To answer this question it is necessary, in the first place, to consider how the matter stands with eyes that do not squint. Now it is commonly found that the vision of those who suffer from the higher degrees of hypermetropia cannot be brought up to the normal standard. Theoretically, of course, when the accommodation has been paralysed and the refractive error has been carefully corrected a satisfactory degree of vision ought to be attained. The human eye, however, is not a mere optical instrument, but a physiological organ, and, whilst enjoying the advantages, is restricted by the limits of its natural constitution. We find accordingly that in the cases we are considering, after the removal of every optical error, there is a deficiency in their visual capacity. It is true that there may be subsequent improvement; the clearer retinal images produced by the use of proper glasses, the increased skill in interpreting retinal impressions, and the gradual development of the originally imperfect eye, may all bear their part in strengthening the powers of vision, but there will be left nevertheless a residual defect which cannot be made good. Just as the most elaborate education, combined with every advantage of circumstance, will be unable to place a man of ordinary mental power on a level with a man of

ability, so the most careful correction and the most assiduous training will fail to make a highly hypermetropic eye the equal in visual capacity of a normal eye. We have here, therefore, an essential visual defect, which is not dependent on the refractive error, but is associated with it. Each has to be regarded as an imperfection, there being wanting in the one case full anatomical development, in the other normal physiological capacity. And each is a congenital condition.

To illustrate the association of these two defects we may use the fixing eyes of the cases we are at present dealing with. The variations in visual power which they showed have been given in Table XVIII, and we have now to add the variations in their refractive condition. To do this the method adopted in constructing Table XVII has been resorted to, and the average degree of hypermetropia in the two principal meridians found for each group of cases. The results appear in the following table:

TABLE XXVII.

Vision in fixing eyes.	Number.	Average degree of hypermetropia.	
		Lower meridian.	Higher meridian.
$\frac{6}{6}$	41	2·96 D.	3·36 D.
$\frac{6}{9}$	15	3·53 D.	4·36 D.
$\frac{6}{12}$	7	3·85 D.	4·21 D.
$\frac{6}{18}$	7	3·78 D.	4·64 D.
$\frac{6}{24}$	3	5·66 D.	7·33 D.

The different degrees of vision here given were, it should be remembered, those attained after full correction of refractive errors whilst the accommodation was paralysed, yet even under those circumstances there was failure in thirty-two of the cases to reach the normal standard. And though these eyes have not enjoyed the advantages of long practice with glasses, it is not to be supposed that their visual deficiencies would thereby be eventually removed. Clearly, then, they suffered from an incapacity of vision independent of refractive defect. But the two defects were closely associated, for as the acuteness of vision declined throughout the successive groups there was an almost regular increase in the average degree of hypermetropia.

In the case of deviating eyes it is taken for granted that something more than mere ametropia, however serious that may be, is required to account for the visual defect. This, of course, is because the correction of refractive error fails to bring about a corresponding improvement of vision. How great the failure may be in a particular series of cases has been shown by our Tables XIX and XXIII, which give the extent and distribution of the amblyopia, both actual and relative, in seventy-five squinting eyes after all their refractive defects have been corrected. It must not, of course, be forgotten that glasses are not absolutely without effect.* In those

* See above, page 55.

cases where the fixing eyes reached the normal standard of vision we found that about 40 per cent. of the deviating eyes could be improved by the use of spectacles, the other 60 per cent. remaining unaffected. Here, where many of the fixing eyes were themselves deficient in visual capacity, about 30 per cent. of their fellow eyes were benefited by correcting glasses, whilst the vision of 70 per cent. remained the same after correction that it was before.

But although the defect of vision is so little dependent on the refractive defect, is the disproportion between the extent of the former and the degree of the latter to be considered so great as to exclude all idea of their being even associated together? Or, on the other hand, do they rise and fall in any kind of unison? By arranging our series of squinting eyes in the same manner as the fixing eyes were dealt with in Table XXVII, we get the figures shown in Table XXVIII.

TABLE XXVIII.

Vision in deviating eyes.	Number.	Average degree of hypermetropia.	
		Lower meridian.	Higher meridian.
$\frac{6}{6}$	4	3·75 D.	3·87 D.
$\frac{6}{9}$	8	2·56 D.	3·75 D.
$\frac{6}{12}$	3	3·33 D.	4·66 D.
$\frac{6}{18}$	15	3·70 D.	4·70 D.
$\frac{6}{24}$	8	4·62 D.	5·62 D.
$\frac{6}{36}$	2	1·75 D.	3·50 D.
$\frac{6}{60}$	8	4·50 D.	6·18 D.
$<\frac{6}{60}$	23	4·06 D.	4·71 D.

There is here a less obvious correspondence between the two factors of defective vision and ametropia than in the former case. In the lower meridians, at any rate, of the successive groups no increase in the average degree of hypermetropia can be traced. In the higher meridians, however, there is with diminishing visual power a progressive, though interrupted, increase in the average degree of refractive defect. The cause of these anomalous results is, without doubt, the frequent occurrence of astigmatism of high degree among squinting eyes, an element which in such calculations is sure to introduce much uncertainty.

The foregoing table, indeed, has been given chiefly for the purpose of comparison with that relating to the fixing eyes, though the results it gives are not without their value, and point, as we have said, to the same conclusion as that arrived at in the former case. But the vision of the deviating eyes, as there stated, bore no reference to the vision of the fellow fixing eyes; that is to say, the relative amblyopia found no place in the table. It is the relative amblyopia, however, which it is most important to compare, if possible, with the attendant refractive conditions. And since those conditions in a group of cases are not quite fairly represented by the average amount of the hypermetropia present in the two principal meridians, some other kind of comparison must be employed. For this purpose we

shall here take, not the actual refractive defect, but the amount of the difference between the ametropia of the one eye and the other. The comparison will thus be between the relative visual defect and the relative refractive defect; one far more true than any based on the actual amblyopia on the one hand, or on the actual ametropia on the other. For though the fixing eye is itself ametropic, yet it must be the standard for its fellow in respect to refraction just as it is in regard to vision.

The difficulty of estimating the refractive difference between two eyes, either or both of which may be astigmatic, has been more than once referred to, and it is no slight one. In only a small proportion of cases can the difference be represented as a purely spherical one, and to take the average degree of hypermetropia in each principal meridian of a series of eyes we have just seen to be unsatisfactory for our present purpose. We have, therefore, to resort to some other method. That now adopted consists in noting in each individual case the amount of the difference between either principal meridian of the deviating eye and the corresponding meridian of the fixing eye, and then grouping the cases according to the maximum difference so found. It will appear at first as an objection to this plan that one or even both of the principal meridians of the squinting eye may present a lower degree of hypermetropia than exists in the fixing eye.

That, in fact, was sometimes the case here, but in almost every instance such an amount of astigmatism was present as to put the deviating eye in a worse position than its fellow, so that the maximum difference between its own principal meridians and those of the fixing eye could still be taken as a fair measure of its refractive inferiority. A greater difficulty lies in the fact, which has been pointed out in the previous section, that occasionally the fixing eye is in respect to refraction certainly the worse of the two. What significance may be attached to this circumstance will be discussed later on, but it is necessary to state here that four instances of the anomaly are to be found among the cases now before us. In three of these there was a purely spherical difference of half a dioptre; in the fourth the depreciation was more serious, but was accompanied and doubtless explained by the presence of slight corneal nebulæ in both eyes. For the purpose of simplicity it has seemed best to treat all the four as exceptional and leave them out of our comparison.

The cases, then, ranged according to the degree of relative amblyopia in the squinting eye, were formed into the following groups:

1st. Those in which there was no appreciable difference between the refraction of the two eyes.

2nd. Those in which neither of the principal meridians of the deviating eye differed by

more than half a dioptre from the corresponding meridian of the fixing eye.

3rd. Those in which such difference did not exceed one dioptre.

4th. Those in which the difference in the case of either principal meridian amounted to more than one dioptre.

We take first the results for the cases showing extreme differences of relative amblyopia : on the one hand, those whose vision was equally good in both eyes; on the other, those whose deviating eyes possessed no useful vision at all. From table XXIX A it will be seen that of the former class more than 40 per cent. were isometropic, whilst no case was found to show a refractive difference of more than one dioptre between the corresponding meridians of the two eyes. In the latter class, however, isometropia occurred in one instance only, a proportion of less than 5 per cent., whilst differences of more than one dioptre were present in more than half of the whole number.

With these results we now compare those drawn from the whole of the sixty-nine cases, forming them into two divisions, of which the first comprises all in which the squinting eye saw at least half as well as its fellow, and the second those in which the relative depreciation of vision went yet further. In the one division, as shown in Table XXIX B, isometropia was found in more than 20 per cent. of the cases, in the other in no

TABLE XXIX A (*extreme cases*).

Symbol of relative amblyopia.	Actual relative defect.	Isometropic.		Difference not more than ·5 D.		Difference not more than 1 D.		Difference more than 1 D.	
		No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
1	0	3	42·85 p. c.	3	42·85 p. c.	1	12·50 p. c.	0	—
10	∞	1	4·34 ,,	7	30·43 ,,	3	13·04 ,,	12	52·17 p. c.

TABLE XXIX B (*all cases together*).

Symbol of relative amblyopia.	Actual relative defect.	Isometropic.		Difference not more than ·5 D.		Difference not more than 1 D.		Difference more than 1 D.	
		No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
1 to 5	0 to ·50	4	21·05 p. c.	5	26·31 p. c.	3	15·78 p. c.	7	36·84 p. c.
6 to 10	·60 to ∞	2	4·00 ,,	14	28·00 ,,	9	18·00 ,,	25	50·00 ,,

more than 4 per cent.; and whilst differences exceeding one dioptre occurred in the former to the extent of only 36·84 per cent., in the latter they were present in just half of all the cases. The conclusion seems to be irresistible that there is a fairly close association between the degree of the relative amblyopia in a squinting eye and the extent of the refractive difference between that eye and its fellow; so that whilst a slight difference of vision more frequently occurs where there is but a low degree of anisometropia, serious relative amblyopia is more likely to be found where great refractive inequality is present.

Such being the facts, how are they to be interpreted? At first it might seem as if we had here some support for the belief that the amblyopia of squint is the result of disuse, since the highest degree of visual defect is most often found in those eyes whose refractive condition is greatly inferior to that of their fellows; and it is just in such cases that "suppression" of the second image must be most easy and most complete. It is not necessary to dispute the latter proposition; "suppression" can and doubtless does take place, and more readily under the circumstances in question, but we need not hold on that account that it is the cause of the amblyopia. The analogy of the fixing eyes leads to a directly opposite conclusion. Among them we found cases of depreciated vision, associated with, but not dependent on, refractive error; among

these we have visual incapacity, in conjunction with, but not due to, optical defect. The deficiencies of the former can only be explained as congenital abnormalities ; there can be no difficulty in accepting a similar origin for those of the latter. In these, as in the others, anatomical defect and physiological incapacity go together as the twofold expression of a primary want of development. A facility in "suppressing" the images appertaining to a squinting eye should therefore be looked on as the consequence rather than the cause of its depreciated visual power.

But though as a rule the degree of relative amblyopia in a deviating eye is associated with the extent of the relative refractive defect, exceptions occur of which we must take note. Of the first kind are the cases with little difference in the refraction, but considerable difference in the vision of the two eyes, and these might be held to exhibit the effect of disuse were they not at least counterbalanced by those of the second kind, which show decided anisometropia but little difference of vision. There is finally a third kind, comprising those few cases, already mentioned, in which the refractive error is actually greater in the fixing than in the squinting eye. It is difficult to imagine how the theory of acquired amblyopia can account for this last variety, and explain the voluntary selection of the worse eye for fixation whilst the better one is abandoned to "suppression" and ultimate blindness. All these

variations, however, can be readily and naturally accounted for on the supposition that the visual incapacity is not acquired, but innate. The general relation which we have found to exist between the visual and the refractive defect would thus have been present from the first, the degree of the one bearing some proportion to the extent of the other; yet this proportion would not always be so exact but that in some cases the anatomical, in others the physiological defect might be the more strongly marked. Hence it would come about that, whilst the general rule holds good, there may be found, on the one hand, little relative amblyopia co-existing with a considerable difference in refraction, and on the other such a depreciation of vision in one eye that its fellow, even though the worse as regards refraction, has to be used for fixation.

The foregoing considerations lead us, therefore, to the belief that the amblyopia so commonly found in eyes that squint is not the result of frequently repeated acts of voluntary suppression, but a defect present from birth. There are nevertheless, as we have already mentioned, two chief difficulties in the way of its acceptance; and these we have now to face.

There is first the fact that diplopia, though ordinarily absent, can, in many cases of convergent strabismus, be artificially evoked. This can only be explained by supposing that binocular vision was formerly present,—a state of things, it

is suggested, impossible except with fairly equal powers of vision in the two eyes. But as a matter of fact binocular vision, though certainly rendered more difficult by the inferiority of one eye, can frequently be accomplished in spite of that drawback, as we may see in many who have never been the subjects of strabismus; so that the demonstration of its previous existence in a squinting patient by no means proves that the eyes were originally of equal visual capacity. Moreover it is not in all cases that this artificial diplopia can be evoked, for in a large proportion of instances it cannot be produced at all, and there is nothing, therefore, to suggest that binocular vision has ever taken place. If it is to be argued that the process of "suppression" has here been so effectually carried out as to destroy all trace of a function which was formerly possible, it is yet equally open to us to hold that such a function has never been developed. The artificial production of diplopia in certain cases of squint cannot, then, be claimed as an argument against supposing the associated visual defect to be congenital.

In the second place, there is the contention that monocular amblyopia is not to be found apart from strabismus, the deduction, of course, being that it owes its existence to the development of the squint. But it is difficult, if not impossible, to maintain this contention in the presence of the facts which have been produced

to show that every degree of monocular visual incapacity is to be discovered, if it be only carefully looked for, among those who have never suffered from strabismus.* It is common enough to find the lower degrees of visual inequality among hypermetropic patients: the higher degrees are, as a matter of course, less frequently met with; and it is only the comparative rarity with which extreme instances of this unilateral defect are noticed that can have given rise to the belief that they do not occur at all. If, then, it be admitted that such a monocular amblyopia may exist among those who do not squint, its occurrence as a congenital condition among those who do, cannot be denied. And its very presence in them, assisting, as it so largely must, in the development of the strabismus, would of itself explain its less frequent appearance in those who are free from squint.

Nor, if once the belief in a congenital inequality of vision between the two eyes be accepted, would it seem to be necessary to look further for an explanation of the convergent strabismus of those hypermetropic individuals in whom such an inequality can be traced. We so often see an artificial squint started in a child through the disadvantage at which one eye is put by the formation of nebulæ in its cornea, that it is easy

* See hereon Schweigger, 'Clinical Investigations on Squint' (English translation), pp. 78, *et seq.*

to suppose a similar result arising naturally from an innate one-sided defect of vision, and nothing further is required to complete the chain of causation leading up to convergent strabismus. More especially would a natural defect of this kind, joined to the hereditary tendency we have found to exist, appear to supply a reason for that occurrence of squint in the early months of life which is otherwise somewhat difficult to account for. But then, as we have seen, there are those who squint and yet have equally good vision in either eye. No relative defect is here present to make the abandonment of binocular vision a matter of indifference, but nevertheless a permanent state of convergence is established, often enough with a degree of hypermetropia that can require no great accommodative effort. The matter will be more properly discussed hereafter in connection with alternating squint; it is enough at this point to insist upon the presence of the phenomenon among cases of monolateral convergence, and to indicate once again that it is possible to over-estimate the importance of the part which hypermetropia plays in the development of convergent strabismus.

It is scarcely needful to say more than a few words as to that view which regards the relative amblyopia as partly congenital and partly acquired. The task of those who hold it is to show that squint causes a progressive deterioration of vision

equally with those who consider the defect to be entirely due to disuse, and the evidence which forbids us to accept the latter belief as true must be adverse also to the former. To demonstrate that the vision of a squinting eye at any particular date is worse than it was at some previous period must in any case be difficult; it cannot certainly be made easier by assuming that part of the defect existed before the squint appeared, for it would then be necessary to define how much of the total amblyopia is primary, and how much of it secondary to the strabismus. If the improvement that sometimes occurs after treatment has been taken in hand is to be regarded as the measure of the acquired amblyopia, this can, after all, form but a small part of the whole defect, for such improvement never attains more than a very moderate degree. And it is far more reasonable to suppose that, in those cases where it can be effected, it is analogous to the improvement wrought in non-squinting hypermetropic eyes by the use of similar means, than to assume that there has come about a recovery of visual power lost through a habit of disuse.

We may, then, sum up the results of our inquiry into the conditions of vision in squinting eyes as follows.

Admitting that in the majority of such eyes the vision is defective, we find that—

i. In a certain number improvement can be

brought about by the correction of refractive error ;

ii The fixing eyes themselves are often visually defective.

The amblyopia of strabismus must therefore be regarded more as a relative than an absolute deficiency ; and, being measured by the standard of vision attainable in the fixing eye, be defined as the defect of vision existing in a squinting eye as compared with its fellow after correction of all refractive errors in both.

Such amblyopia may, in a series of cases, be of all degrees from zero to infinity ; and by assuming the equality of all the fixing eyes, and thus ranging the deviating eyes according to a single uniform standard, it was found that in the present series—

i. Extreme relative amblyopia occurred in just one third of the cases ;

ii. In one tenth of their number there was no relative amblyopia whatever ;

and further, that among the different classes of cases—

i Whilst equality of vision was very evenly distributed throughout,

ii. The highest degree of relative amblyopia was to be found just twice as often among those in whom the vision of the fixing eye was depreciated as among those in whom it reached the normal standard.

From these facts we are entitled to assume—

i. That when the vision of both eyes is defective the common defect must be due to a common cause, and that this can be nothing else than congenital disability.

ii. That if it be admitted that the two eyes may suffer from such congenital disability in unequal degrees, no further explanation of the amblyopia of strabismus is required.

iii. But that if so much only of the defect as is common to both can be regarded as congenital, and the excess in the deviating eye is to be taken as the result of disuse, equality of vision cannot be explained except by supposing that there has not been sufficient time since the onset of the squint for deterioration to take place.

The extent of the deterioration does not, however, appear to depend upon the time the squint may have lasted, since no correspondence could be traced—

i. Between the degree of the amblyopia and the age of the patients at their first appearance;

ii. Between the degree of the amblyopia and the actual duration of the strabismus in those cases where it could be ascertained. In this latter comparison—

(*a*) Not only could no general relation between the two factors in question be made out, but—

(*b*) In individual cases long duration was found associated with equality of vision, and short duration with high relative amblyopia;

(*c*) Both of these varieties occurred in such proportions as to prevent their being regarded as exceptional.

In respect to a connection between the refractive conditions and the vision in convergent strabismus, we find—

A. That in a certain proportion of non-squinting hypermetropic eyes the vision cannot be brought up to the normal standard, in spite of—

i. Full correction of all refractive error;

ii. The influence of education;

iii. The further natural development of the eye; a residual defect being left, which, though not dependent on, is in its extent closely associated with the degree of the refractive defect. The former, like the latter, must be a congenital imperfection.

B. In squinting eyes, though the same direct association is less easy to trace on account of the more frequent presence of astigmatism, yet as a general rule the degree of relative amblyopia bears a relation to the extent of the refractive difference between the eyes. By analogy with the fixing eyes, the visual defect in the deviating eyes should thus be held to be of congenital origin—a theory on which the variations from the general rule can be naturally accounted for.

The foregoing reasons compel us to hold the belief that the ambyopia of strabismus is not developed by a long-continued habit of "suppression," but is a primary congenital defect.

Of the two chief difficulties in the way of its acceptance—

i. The fact that the artificial diplopia which can sometimes be evoked, implying a former power of binocular vision, points to an original equality in the two eyes, is met by the considerations—

(*a*) That such equality is not absolutely necessary for binocular vision;

(*b*) That in a large number of cases no artificial diplopia can be evoked, and hence there is no evidence that binocular vision has ever been present to them;

ii. The belief that monocular amblyopia does not occur apart from strabismus is not borne out by facts.

The theory that the visual defect is partly congenital and partly acquired is untenable because—

i. The evidence telling against progressive deterioration is adverse to it;

ii. The better vision sometimes occurring after treatment is never great, and is more probably a new acquisition than a recovery of what has been lost.

A congenital inequality of vision, associated with hypermetropia, is a sufficient explanation of the development of convergent strabismus; and,

when joined to hereditary tendency, is the probable cause of its onset at the earliest periods of life. Some other origin, however, has to be sought for those cases of squint which possess equally good vision in either eye, and suffer from only a moderate degree of hypermetropia.

SECTION V.

ALTERNATING CONVERGENT STRABISMUS.

The term alternating strabismus, implying the alternate use of either eye for fixation by a person suffering from squint, has been used to include two very different conditions. The first is that in which, owing to the presence of a high degree of anisometropia, the one eye being either normal or hypermetropic is employed for distant, the other being myopic is used for near vision. This is indeed the only form of alternating strabismus recognised by some writers.* The second is that in which, by reason of the visual equality of the two eyes, either is used indifferently in both near and distant vision. In the former case there is certainly an alternation in the use of the eyes, but only when the work that has to be done is changed. The task remaining the same, it is always the same eye which does it, and the squint therefore is not in any real sense alternating. In the latter case, however, though the task remain the same, the eye which is at one time called upon to perform it may at another be replaced

* See Fuchs, 'Lehrbuch der Augenheilkunde,' 2nd edit., 1891, p. 624.

by its fellow. There is here a true alternation, and it is with this condition, associated with a convergent squint, that we have now to deal.*

Such an alternating convergent strabismus was found in twelve of the patients comprised in our series, a proportion of 8·88 per cent. of the whole number of cases of constant squint. This, we believe, fairly represents its relative frequency in general.†

Our attention is naturally drawn in the first place to the refractive conditions present in these cases, and, as might be expected, we find that they differ from those with which we have become familiar as prevailing in monolateral strabismus. On the one hand there is remarkably little inequality between the eyes in individual patients; on the other, the actual defect rarely attains more than a very moderate degree.

In estimating the former of these factors we begin by employing the method adopted in the last section, and shown in Tables XXIX A and B,‡

* The test of alternating squint is concisely stated by Mr. Adams Frost, "I have considered a squint as alternating when either eye can be made to fix an object, and remains the fixing eye after a momentary closure of the lids" ('British Medical Journal,' 1887, ii, p. 663).

† Mr. Adams Frost states that he has "found that about 5 per cent. of all cases of squint are alternating." Paper quoted above. Other observers give the proportion of such as something over 10 per cent.

‡ See above, p. 84.

by which the cases are grouped according to the amount of the refractive difference between the corresponding principal meridians of the two eyes.

TABLE XXX.

Isometropic.		Difference not more than ·5 D.		Difference not more than 1 D.		Difference more than 1 D.	
No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
3	per cent. 25·00	5	per cent. 41·66	3	per cent. 25·00	1	per cent. 8·33

We find from Table XXX that isometropia was present in one fourth of all the cases, and that in as many as two fifths such inequality as there was did not exceed half a dioptre. So that in one third only of the total number did the refractive difference amount to as much as one dioptre. We may doubt whether equally favourable conditions in this respect would be found to exist in any twelve non-squinting hypermetropes taken at random.

In the present case, we may point out, there is even less ambiguity in the results obtained by this method than when it was made use of on the last occasion. For then, as we saw, the presence of astigmatism of high degree in a deviating eye would sometimes give a fictitious advantage to that eye, at least as regards its lower principal meridian, and make the actual refractive difference between it and its fellow appear somewhat less

than the reality. Here, however, no such difficulty occurs. It is not that astigmatism was absent, since two thirds of all the eyes suffered from compound hypermetropic astigmatism, but that in no case did the hypermetropia of an eye exceed that of its fellow in one principal meridian, whilst falling short of it in another. When, that is, both meridians of the one eye differed from the corresponding meridians of the other, the difference manifested by each, though not always of the same degree, was yet always in the same direction.

Relying on this circumstance, we may now also with some confidence make comparison of the average degree of hypermetropia present in the principal meridians throughout the successive pairs of eyes. We cannot, indeed, classify these eyes as "fixing" or "deviating," since each may assume either character, but we can arrange them according to the higher or lower degree of ametropia that they may present. Thus dealt with they give us the results shown in the following table:

TABLE XXXI.

Average degree of hypermetropia in the less ametropic eyes.		Average degree of hypermetropia in the more ametropic eyes.	
Lower meridian.	Higher meridian.	Lower meridian.	Higher meridian.
2·25 D.	2·75 D.	2·58 D.	3·29 D.

The more ametropic eyes in their lower meridians suffered from an average degree of hypermetropia only one third of a dioptre higher than that present in the less defective eyes, whilst the latter in the higher meridians enjoyed an advantage of little more than half a dioptre. Let us compare these differences with those existing between the fixing and deviating eyes of a number of persons with monocular strabismus. Table XVII A,* though drawn up for a different purpose, will supply the data we require. Now, in spite of the fact that, as regards the lower meridian, the difference was frequently in favour of the deviating eye, we yet find that in most of the series of patients there given the difference between one or other meridian of the squinting eyes and the corresponding meridian of the fixing eyes was decidedly greater than that shown by the cases of alternating strabismus, and such difference would certainly have appeared greater still but for the disturbing factor referred to.

We may hold then, as characteristic of alternating squint, that there is usually little refractive difference between the eyes; in a large majority of cases, indeed, practically none at all.

And if the refractive difference between the eyes is slight, so also is the actual hypermetropia of but very moderate degree. We may make a

* See above, p. 44.

threefold comparison in this respect between these eyes and those in which the squint was monolateral.

In the first instance we may compare the figures given in Table XXXI with those in Tables XXVII and XXVIII,* where is shown the average degree of hypermetropia in each principal meridian of the fixing and deviating eyes respectively in various classes of monolateral cases, whose visual conditions we lately examined. It will be seen that the advantage is all on the side of the eyes with alternating squint. The average defect even in the more ametropic of these is distinctly less than that present in the best of the fixing eyes of the monolateral cases, the difference being more strongly marked where the other classes of the latter and where the deviating eyes are concerned.

So again, we may ascertain the extreme limits

TABLE XXXII.

Cases classed according to the degree of astigmatism.	Range of defect in lower meridians.	
	Less ametropic eyes.	More ametropic eyes.
No astigmatism . . .	1·0 D. to 3·5 D.	1·5 D. to 3·0 D.
Astigmatism = ·5 D. . .	·5 D. to 5·0 D.	·5 D. to 2·5 D.
Astigmatism = 1·0 D. . .	2·0 D. to 7·0 D.	1·0 D. to 3·0 D.
Astigmatism over 1 D. . .	—	2·0 D. to 7·0 D.

* See above, pp. 77, 79.

of ametropia that may be reached, and contrast the range of defect with that which we found possible in monolateral squint. The latter was shown in Table X ; * in Table XXXII are given the corresponding facts for the alternating cases. In almost every class of these the hypermetropia reached a far lower level, and but for one exceptional case the difference would have appeared yet more pronounced.

Lastly, we may point to the actual proportion in which cases with a moderate degree of hypermetropia occur. It may be remembered that in discussing the relation between the extent of the convergence and the degree of hypermetropia in monolateral squint,† we noted how large a number of cases suffered from only a low degree of refractive defect in the fixing eye. In nearly one fourth of the whole number of those cases the hypermetropia did not exceed 2·5 D. in the higher meridian. Here, however, we find that degree of hypermetropia not exceeded in as many as one half, even of the more ametropic eyes, whilst of the less defective eyes nearly three fifths (58·33 per cent.) were in the same favourable position. And it may be added that in 41·66 per cent. of the latter class, and in 25·00 per cent. of the former, the hypermetropia did not rise beyond 1·5 D.

It is clear, therefore, that not only is there

* See above, p. 23.

† See above, p. 37.

little refractive difference, as a rule, between the eyes of one suffering from alternating strabismus, but that in most of those so affected the total refractive defect is of but inconsiderable extent.

As it is with the refraction, so also is it with the vision. For in these cases we find on the one hand a high degree of visual capacity, on the other, little appreciable difference between the eyes of each individual.

We may take the latter point first. Of our twelve cases, nine were available for the examination of their vision. In as many as five of these, both eyes saw equally well; in none of them was the worse eye possessed of less than half the acuteness of vision present in the other. The whole result is presented in Table XXXIII, which should be compared with Table XXIII* in order

TABLE XXXIII.

Symbol of relative amblyopia.	Actual relative defect.	Number.	Proportion.
1	0	5	55·55 per cent.
2	·25	1	11·11 „
3	·33	1	11·11 „
4	·40	0	—
5	·50	2	22·22 per cent.

that the immense advantage which the alternating cases enjoyed in this respect over the monolateral may be fully appreciated. There, one third of

* See above, p. 64.

the deviating eyes possessed no useful vision at all; here, such a condition was entirely absent: in 70 per cent. of those cases the vision of the squinting eye was less than half of that in the fellow fixing eye; in these, none of the less capable eyes reached that degree of depreciation: there, lastly, the proportion in which equality of vision existed was but 10·66 per cent.; here, it amounted to 55·55 per cent.

And in regard to the actual acuteness of vision a similar superiority was to be found. Although in a majority of the cases, as we have just seen, there was an absolute equality in the visual power of the two eyes, yet there was difference enough in each of the rest to enable us to form the whole number, for purposes of comparison, into two categories, a better and a worse. Thus arranged as in Table XXXIV, we see on one side

TABLE XXXIV.

Better eyes.			Worse eyes.		
Vision.	No.	Proportion.	Vision.	No.	Proportion.
$\frac{6}{6}$ Snellen	8	88·88 per cent.	$\frac{6}{6}$ Snellen	5	55·55 per cent.
$\frac{6}{9}$ „	1	11·11 „	$\frac{6}{9}$ „	1	11·11 „
			$\frac{6}{12}$ „	3	44·44 „

all but one possessed of normal acuteness of vision, on the other more than half attaining the same level. But if we turn to Table XIX* we

* See above, p. 59.

find that out of seventy-five deviating eyes in the monolateral series four only, that is 5·33 per cent., reached the standard of normal vision; whilst among the fixing eyes, as shown in Table XVIII,* the proportion (56·00 per cent.) occupying this position was just about the same as in the worse class (55·55 per cent.) of the alternating series. It may be that with a larger number of alternating cases somewhat different ratios might result, but the broad fact of the distinction between these cases and the monolateral is too clear to be denied. It is only that small minority of the latter, where good vision and low refractive defect are present in both eyes, that exhibits conditions at all comparable with those which are usually to be found in cases of alternating strabismus.

But further. It will be conjectured that where, as in these alternating cases, the visual and the refractive conditions are so very similar, a pretty close relation must subsist between them; so that in those eyes where the vision is at its best will the hypermetropia reach its lowest level, and in those individuals whose eyes show least visual difference will the refractive difference be least pronounced.

Such is actually the case. Table XXXV A shows how low was the average degree of hypermetropia in those of the better eyes whose vision came up to the normal standard; in

* See above, p. 58.

TABLE XXXV A (*better eyes*).

Vision.	Number.	Average degree of hypermetropia.	
		Lower meridian.	Higher meridian.
$\frac{6}{6}$	8	1·31 D.	1·62 D.
$\frac{6}{9}$	1	2·00 D.	3·00 D.

Table XXXV B, are indicated the relative relations therein among the different sections of the

TABLE XXXV B (*worse eyes*).

Vision.	Number.	Average degree of hypermetropia.	
		Lower meridian.	Higher meridian.
$\frac{6}{6}$	5	1·50 D.	1·80 D.
$\frac{6}{9}$	1	3·00 D.	3·00 D.
$\frac{6}{12}$	3	1·83 D.	3·00 D.

worse eyes. Even in this small number of cases the association between good vision and slight refractive defect is sufficiently apparent.

In respect to the correlation of equality of vision and equality of refraction, it is enough to point out that among the five individuals whose eyes were of equal visual power, none showed anisometropia exceeding half a dioptre.

The relation, then, between the two factors of vision and refraction, which we found existing in monolateral squint, is in the alternating form yet more intimate and more exact.

There is, then, a striking contrast between these two forms of convergent strabismus, the monolateral and the alternating. Does this imply that each is to be regarded as something quite distinct, an affection *sui generis*, or may either change its character? We may be sure that a monolateral squint never becomes anything else, but is it not possible for the alternating form to change into the monolateral? We believe that it may. It is sometimes extremely difficult to make out to which class a particular case should be assigned, and occasionally one which at first used to alternate is found—and that without the intervention of any damaging influence—to have become monolateral. It seems likely, indeed, that most of that small minority among the monolateral cases, which resemble the alternating in the good vision they possess, and the low degree of hypermetropia which they manifest in either eye, may at an earlier period have actually belonged to the latter class. They form, in any case, a connecting link between these, which, but for their squint, so nearly resemble normal eyes, and those others which, in addition to their squint, present the extreme of ametropic defect and visual incapacity.

It must not be supposed, however, that alternating is but a preliminary stage of monolateral strabismus. To what extent the one form may merge in the other we cannot tell, but it is quite

certain that an alternating squint may retain its special character for an indefinite period. This is clear enough in the cases before us.

TABLE XXXVI.

Age at first visit.	Number.	Proportion.	Average previous duration.	Average amount of convergence.
		per cent.		
Under 5 years .	1	8·33	2·00 years	30·00°
From 5 to 10 years	5	41·68	5·00 ,,	30·20
,, 10 to 15 ,,	4	33·33	9·75 ,,	21·20
,, 15 to 20 ,,	1	8·34	16·00 ,,	35·00
Over 20 years . .	1	8·33	20·00 ,,	20·00

Where nearly all show an average duration, before coming for treatment, of five years and upwards, it is impossible to believe that any further change can be impending in the relations of the eyes to each other. We may, in fact, regard those who suffer from alternating squint as holding a position at one end of a series, which, comprising all cases of hypermetropic convergent strabismus, presents every possible gradation of visual and refractive defect, and terminates with those who, to the disadvantages of a high degree of hypermetropia, add the loss of the power of fixation in the squinting eye.*

* Mr. Adams Frost's conclusions partly agree with and partly differ from those given above. In the paper already referred to he says, "I formerly believed that most cases of squint were alternating at first, but now it seems to me more probable that most cases that are really alternating remain so throughout. I

But if, on the one hand, cases of alternating squint are connected through such a series with the most pronounced examples of monolateral squint, it is impossible to avoid seeing, on the other, how very little removed they are from the ordinary run of slightly hypermetropic individuals, or even from those with no perceptible fault of vision or refraction. For their refractive defect is usually insignificant in degree, and it is only exceptionally that their vision falls below the normal standard. But for their squint most of them might be considered as having nothing the matter with them.

Why, then, should they squint at all? Strangely enough, it is not to this point that discussion is usually directed, but to the subordinate one of why there should be alternation. It seems to be assumed that, as in the monolateral form, there is a certain degree of hypermetropia present which provokes excessive convergence, and that the alternating character of the squint is the difficulty requiring explanation. And it is further suggested that it is the alternation which, bringing each eye into frequent use, prevents the visual deterioration of either.

But if this last proposition be true, how comes it that both eyes may see equally well in certain cases of monolateral squint? Some of these,

have certainly never seen an alternating squint become fixed in one eye, nor do I think that the boundary line between alternating and fixed squint is as sharply defined as it was formerly thought to be" ('British Medical Journal,' 1887, ii, p. 663).

as we have mentioned just above, certainly alternated at first. If alternation maintained their eyes in a state of visual equality while it lasted, its cessation ought to have had a prejudicial effect upon that eye which abandoned the habit of fixation. Yet no such deterioration followed. We have seen, moreover, how closely associated are the vision and the refraction in alternating strabismus, an equality of visual power in the eyes being usually correlated with similarity of optical conditions. Are we to assume that alternate use of the eyes keeps them in a condition of refractive, as well as of visual equilibrium? Surely we must hold that the truth lies in the very reverse of what is suggested, and that it is the primary visual equality of the eyes, assisted by their refractive similarity, which hinders fixation from becoming the exclusive function of one of them.

It is not, therefore, so much the alternating character of the squint as the fact of there being any squint whatever, that constitutes the difficulty in these cases. We can understand how, even with a low degree of hypermetropia, squint may be developed, provided a certain amount of relative amblyopia be present in one eye, and instances thereof occurred in our monolateral series. But here, with few exceptions, the influence of ametropia was reduced to a minimum, and relative amblyopia did not exist. Clearly, the cause could not lie in the local conditions.

Where then are we to search for it? In trying to answer this question we shall obtain some guidance if we know at what period of life the squint usually appeared. It will be remembered that in the case of those with monolateral strabismus, we took the end of the fifth year as a dividing line, and found that in 75·45 per cent. the squint began before, in 24·54 per cent. after that date.* If we apply the same test to our alternating cases, we find from Table XXXVII that in as many as 91·66 per cent. the onset occurred during the earlier, in only 8·33 per cent. during the later period.

TABLE XXXVII.

Period of onset.	Number.	Proportion.
Under 5 years . . .	11	91·66 per cent.
Over 5 years . . .	1	8·33 ,,

The conclusion that this form of strabismus is essentially an affection of infancy is strongly confirmed by fixing a yet closer limit, and taking the end of the third year as the crucial date. The effect of so doing is shown in Table XXXVIII A; whilst, for the sake of comparison, the result of dealing in the same way with the monolateral cases is given in Table XXXVIII B.

In all but a small minority of the alternating

* See above, p. 12.

cases the squint came on before the beginning of the fourth year.* Heredity here does not seem

TABLE XXXVIII A (*alternating cases*).

Period of onset.	Number.	Proportion.
Under 3 years . . .	10	83·33 per cent.
Over 3 years . . .	2	16·66 ,,

TABLE XXXVIII B (*monolateral cases*).

Period of onset.	Number.	Proportion.
Under 3 years . . .	44	40·00 per cent.
Over 3 years . . .	66	60·00 ,,

to play any great part, for in two instances only could its influence be clearly traced, but even were this otherwise, it would still be necessary to look for some definite exciting cause. And it appears at least likely that this might prove to be the nervous disturbance so often attendant upon the eruption of the temporary teeth. During the convulsions to which this so com-

* Messrs. Lang and Barrett suggest that alternation is specially common among those who begin to squint after they have passed their fifth year, since out of 34 of such cases 10 were found to alternate—a proportion of 29·41 per cent. They do not state, however, how many of those of their series in which the onset occurred during the first five years of life, 161 in number, were subject to alternating squint ('Roy. Lond. Ophth. Hosp. Reps.,' vol. xii, p. 140).

monly gives rise squinting actually occurs, and though the deviation then set up is doubtless in many cases only temporary, yet it may be renewed with the accession of a fresh fit. It is easy, then, to imagine that its frequent repetition, or even its manifestation in a single strong spasm, may be enough to upset for ever the complex co-ordination of the ocular movements at a time of life when this has not yet been strengthened by long habit, perhaps not yet completely established. When we remember what serious permanent results the same cause may bring about, there need be no reason for wonder if one of its effects should sometimes be the loss of binocular fixation of the eyes, though every local condition may favour the maintenance thereof. To assume so much is not to exclude the possible action of other influences, which, differing in most other respects, resemble dentition in their power of damaging the nervous system of children, such as intestinal troubles, measles and other febrile disorders. Both these latter and the former seem to have been at work among our present cases, the largest share being borne by dentition. To it was attributed the onset of the squint in just half of the number in which a definite proximate cause was suggested by the parents.

This view, moreover, of the origin of alternating strabismus has this in its favour, that it accounts for the want of relation shown in

Table XXXVI,* between the extent of the deviation and the time that the squint has lasted. For when once the exciting cause has ceased to work there is an end of the damage to which the patient's nervous system is liable. The mischief has been done and is permanent, but in the absence of serious refractive error there is nothing to provoke further convergence. The attack has spent its force, and no more harm can be wrought.

But if such be the origin of the strabismus in cases of the alternating variety, may not some of those which are monolateral even from the first arise in the same way? We have seen that many of these begin to squint long before they have become liable to any particular strain on the accommodation, and that the degree of hypermetropia present is often insufficient to call forth undue convergence. The only circumstances which seemed to account for an early onset were two—hereditary tendency† and relative amblyopia.‡ Yet the latter factor may be absent altogether; the former, though it may have a strong predisposing influence, is scarcely enough of itself to induce the deformity. Reflex nervous disturbances take place among these cases as among the others; they seem to us to constitute a sufficient and probable cause of

* See above, p. 109.
† See above, p. 14.
‡ See above, p. 89.

either form of strabismus. And a slight degree of anisometropia, a small difference in visual capacity, would readily bring about the manifestation of the squint by one eye only, rather than by each alternately.

We hold, then, that there are two kinds of causes at work in the production of convergent strabismus. The one is to be found in the difficulties created by congenital abnormalities of the eyes themselves, the other in a disturbance of the co-ordinating centres of the ocular movements, set up by external irritation of the nervous system. Whilst the former will produce squint in those who suffer from a high degree of hypermetropia and decided relative amblyopia, the latter will account for its development in those whose ocular conditions are practically normal. And we can hardly doubt that each bears a part in the creation of that large class, which stands midway between these two extremes. To their united action, indeed, may be due the fact—if it really be a fact*—that squint is more frequently developed in persons with a moderate, than in those with a high degree of hypermetropic defect. Yet, though that may not be the case, and though the influences we have discussed may not be all that are concerned in the development of this affection, it is certain that nothing can be considered sufficient which

* See above, p. 38.

does not account for the origin of alternating squint. In the explanation of that lies the key to the ætiology of convergent strabismus.

True alternating convergent strabismus, therefore, is that condition in which, with a permanent inward squint, either eye is used indifferently for fixation.

This variety differs from the monolateral as regards refraction, in that—

i. As a rule, there is little or no refractive difference between the eyes;

ii. The degree of hypermetropia to be found in them is usually slight.

It also differs therefrom in regard to the vision, since—

i. The visual capacity of the eyes is nearly or quite the same;

ii. The actual acuteness of vision generally attains the normal standard in both eyes.

And, further, the relation between the state of the vision and the state of the refraction is more intimate and more exact.

Nevertheless alternating squint may sometimes become monolateral, but is not on that account to be regarded as a mere preliminary stage of the latter form, inasmuch as it may retain its special character for an indefinite time.

The fact of the visual and refractive conditions varying so little from the normal makes the

explanation of alternating squint difficult, as the usual theory of convergent strabismus cannot apply. In reference to this question we must hold—

i. That the alternation is the result, and not, as sometimes suggested, the cause of the visual equality of the eyes;

ii. That the early onset of the alternating form of squint points to its being essentially an affection of infancy;

iii. That it is probably caused by those infantile disorders which set up nervous disturbance, especially such as are connected with dentition;

iv. That this view offers a rational explanation of the want of relation that is to be noticed between the extent of the squint, and the length of time it has been present.

Hence two principal kinds of causes are at work in producing convergent strabismus, the one consisting in congenital defects of the eyes themselves, the other in disturbances of the nervous system. Either is sufficient of itself to bring on squint, but it is likely that in the majority of cases both assist in its development. No explanation of convergent strabismus will suffice that does not account for the origin of the alternating variety thereof.

SECTION VI.

THE TREATMENT OF CONVERGENT STRABISMUS.

Before the close connection between convergent strabismus and hypermetropia was recognised, the only method of dealing with the deformity was by operation. But when it was seen how important an element in the matter is the state of the refraction, efforts were naturally made to cure the deviation by the use of connecting glasses. Even now, however, it may be doubted whether any systematic line of treatment is generally followed in these cases, and, in particular, whether any sort of rule as to the employment of one method or the other can be said to be established. To assist in the laying down of some general propositions on these points is the chief purpose of the present essay.

The object aimed at in the treatment of all cases of squint is, of course, the restoration of the deviating eye to its proper position, but to this must be added in suitable instances the re-establishment of binocular vision. The latter we endeavour to effect by means of orthoptic training; for the former, which is its essential

preliminary, resort is made to spectacles or to operative measures.

Now to tell how far the correction of optical error may suffice by itself to bring about parallelism of the optic axes in distant vision, it is necessary to observe its effects in a number of cases taken as they come, without any kind of selection. This test has been applied to the cases we have before us, with the single reservation that those having nebulous corneæ were rejected. The details of the method have been described in Section I, and there is no need to recapitulate them here. Many patients, of course, never presented themselves a second time, but a sufficient number kept up their attendance long enough to afford the data required.*

A. Dealing first with the monolateral cases, we find that in 94 out of the 120 whose refraction we examined in Section III, a record of treatment was obtained, extending over periods ranging from three months to nearly four and a half years.

We begin, then, by noting the effects produced upon the convergence by this method, all favouring or retarding circumstances being for the

* With the results here obtained should be compared those arrived at by Messrs. Lang and Barrett, drawn from observations made upon 102 patients, among whom were included, however, a few with squinting myopic eyes and some with corneal nebulæ. Apparently also monolateral and alternating cases were massed together in their series ('Roy. Lond. Ophth. Hosp. Reps.,' vol. xii, p. 7, *et seq.*).

moment disregarded. The cases may be arranged in three classes: (i) Those which showed improvement both with and without the glasses, and which might therefore be considered as permanently benefited; (ii) Those in whom the improvement was manifest only whilst the glasses were being worn; (iii) Those which either were not improved at all or showed actual deterioration.

TABLE XXXIX.

Cases ranged according to the degree of improvement effected.	No.	Proportion.	Average length of treatment.
Improved both with and without glasses	58	61·70 p.c.	18·82 months.
Improved only when wearing glasses	29	30·85 ,,	20·03 ,,
Not improved, or deteriorated	7	7·44 ,,	25·42 ,,

From Table XXXIX we learn that in less than 8 per cent. did the glasses fail to lessen the convergence, and that in more than 60 per cent. permanent improvement was effected, results equally remarkable and satisfactory. Nor were these due simply to the longer or shorter time that the treatment was kept up; for, as the table shows, the average period during which glasses were worn was shortest in the class where the best effects were obtained, and longest in that where no benefit at all resulted. Such being the general effect of the use of correcting glasses, it is incumbent upon us to examine the conditions under which improvement takes place,

and to ascertain the extent to which it may proceed.

We will take the latter question first. Now the utmost limit of improvement can be nothing short of complete cure, and our task, therefore, must be to inquire how many of our cases were cured by the use of spectacles alone. We must know, however, what is to be understood when we speak of cure in connection with squint. Putting aside any question of binocular vision, an ideal cure, of course, would be one in which the normal position of the eyes was regained without the necessity of wearing glasses any longer. But such a result cannot often be looked for. Squint or no squint, the presence of hypermetropia will compel most patients to the more or less constant use of glasses, so that we may fairly consider that a cure has been attained, when, though the glasses cannot be discarded, convergence is no longer present during distant vision.

Table XL gives us some measure of the success

TABLE XL.

Cases ranged according to the degree of cure effected.	No.	Proportion.	Average length of treatment.
		per cent.	
Cured both with and without glasses	12	12·76	26·18 months.
Cured only when wearing glasses	17	18·08	15·23 ,,
Improved, but not cured .	58	61·70	19·41 ,,
Not improved, or deteriorated	7	7·44	25·42 ,,

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that may be looked for among a number of cases, of every age and every degree of convergence. Assuming that glasses must in any case be worn, more than 30 per cent., that is, nearly one third of the total, were entirely relieved of their deformity; whilst in a substantial number of these, forming nearly 13 per cent. of the whole, the constant use of glasses was not necessary to maintain the cure. Improvement short of cure was effected in nearly two thirds of the cases, and, as we have already seen, there was a small residue upon which no effect at all was produced. In regard to those in whom no convergence was manifest whilst the glasses were off, it is not, of course, to be supposed that the use of these was at once discontinued except for near work. That would doubtless have sometimes led to a relapse, and would in any case have been undesirable in young hypermetropic patients. Yet for many of them such a proceeding would in course of time become perfectly safe, nor is it claiming too much to speak of all of them as cured so far as their squint is concerned. How far, and under what conditions, the glasses may be laid aside we shall see hereafter.

The general result, therefore, is that the methodical use of correcting glasses does substantial good in all but a few cases of convergent strabismus; that in about one out of every three patients, the convergence can be abolished, subject to the continuous use of the glasses;

and that about one in every eight can be enabled to maintain a correct position of the eyes even without their assistance.

Now it is essential that we should make out as far as possible what circumstances conduce to or hinder a favourable result under this method of treatment. Though the factors concerned are so various, we shall find that it is yet possible, taking each of the more important of them in turn, to arrive at some definite principles for our guidance. But it must be remembered that here, as everywhere else, general rules are subject to exceptions, so that cases from which stubborn resistance was to be expected are found to yield rapidly and completely to the influence of glasses, whilst others, at first regarded as specially suitable for spectacle treatment, show themselves but little amenable thereto.

In the first place then, we naturally inquire whether the degree of convergence existing when treatment is begun has any influence on the result. By dividing the cases according to the amount of their original deviation we form them into five classes, the numbers, proportionate extent, and average convergence of each of which are set out in Table XLI.

Our present business is to see how these different classes behaved under spectacle treatment. Table XLII will show us how often improvement, permanent or temporary, and how often failure occurred in each class. It will be

Table XLI.

Original amount of convergence.	Number.	Proportion.	Average amount of convergence.
Up to 10° . .	11	11·70 per cent.	9·45°
10 to 20 . .	36	38·29 „	17·38
20 to 30 . .	32	34·04 „	27·25
30 to 40 . .	13	13·82 „	36·30
Over 40 . .	2	2·12 „	45·00

Table XLII.

Original amount of convergence.	Improved with and without glasses.		Improved only when wearing glasses.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cent.		per cent.		per cent.
Up to 10°	9	81·81	1	9·09	1	9·09
10° to 20	20	55·55	11	30·55	5	13·88
20 to 30	19	59·37	12	37·50	1	3·12
30 to 40	8	61·53	5	38·46		
Over 40	2	100·00				

noted on the one hand that good results were brought about in each class, that is to say, that permanent improvement occurred whatever the original degree of the squint might have been; and on the other, that in a certain number of cases no improvement followed, though the convergence was at first of only moderate extent. It was among the lowest degrees indeed that failure almost exclusively occurred. Are we to conclude then that the result is independent of the original degree of convergence? By no means. For if we turn from the question of mere improvement

Table XLIII.

Original amount of convergence.	Cured with and without glasses.		Cured only when wearing glasses.		Improved but not cured.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
Up to 10°	7	63·63 per cent.	2	18·18 per cent.	1	9·09 per cent.	1	9·09 per cent.
10° to 20	4	11·11 ,,	7	19·44 ,,	20	55·55 ,,	5	13·88 ,,
20 to 30	1	3·12 ,,	6	18·75 ,,	24	75·00 ,,	1	3·12 ,,
30 to 40	—	—	2	15·38 ,,	11	84·61 ,,		
Over 40	—	—	—	—	2	100·00 ,,		

to that of cure, we shall find that the possibility of entirely removing the squint depends very much upon the extent that had previously been reached. Table XLIII shows that the largest proportion of cases in which convergence was altogether abolished was to be found in the class which suffered from the least degree of squint to begin with, a proportion which became smaller in each succeeding class, and disappeared entirely from those where the primary deviation exceeded 30°. And whilst the proportion of those which were cured as long as the spectacles were in use varied little throughout the different classes, the ratio of such as underwent improvement, but improvement short of cure, was lowest among the least severe, and increased steadily to a maximum among the most severe cases.

The general result will be yet clearer if we put aside those few cases which were not benefited, and compare by means of Table XLIV the original average degree of convergence with that left after the glasses had done their work. The

TABLE XLIV.

Original amount of convergence.	No.	Original average convergence.	Final average convergence with glasses off.	Final average convergence with glasses on.
Up to 10°	10	9·30°	2·00°	·50°
10° to 20	31	17·45	11·41	5·54
20 to 30	31	27·32	19·90	10·87
30 to 40	13	36·30	29·46	17·38
Over 40	2	45·00	25·50	17·50

squint was largely reduced in every case, but still bore a general relation to what it had formerly been, its final average measurement showing a regularly increasing gradation throughout the successive classes.

The state of things then was as follows:—On the one hand was a small minority upon which the wearing of glasses had no effect; on the other a large majority upon which a great effect was produced, but an effect not unlimited. Just as when left alone, squint, once started, increases steadily up to a maximum degree at which it becomes stationary; so, when the most potent factor in its production is removed, will it diminish again, but only to a certain definite extent determined by the conditions of the particular case. If, therefore, the convergence, when treatment is begun, be of only moderate degree, we may usually look for its complete removal; if it be extensive, improvement, but improvement short of cure, will be the result.

Without any doubt, this element of the original degree of the squint is the most important in determining the ultimate result. It is, of course, no more than the expression of the amount of mischief which has been wrought, but the further that mischief has gone the more difficult must it be to remedy. And we have to remember that the only effect of glasses is to remove the necessity for special accommodative effort on the part of the patient, and that, as we saw in the last

section, in many cases hypermetropia is not the only cause at work in bringing about convergent strabismus. Hence it is that we shall find other factors playing a less important part in the matter than we should have expected.

This is seen to some extent even in the case of the refraction. We should naturally suppose that the degree of optical defect would have a decided influence on the results to be obtained from the use of glasses, more particularly since there is usually a pretty close relation between the degree of hypermetropia and the extent of the squint. But though such an influence is to be traced, it is not—at least as far as the present cases are concerned—a specially strong one. In Table XLV A the cases which

TABLE XLV A (*non-astigmatic cases only*).

Degree of hypermetropia.	Improved with and without glasses.		Improved only when wearing glasses.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cent.		per cent.		per cent.
Up to 2 D. .	10	71·42	3	21·42	1	7·14
2 D. to 4 D.	8	66·66	2	16·66	2	16·66
4 D. to 6 D.	3	37·50	5	62·50		
6 D. to 8 D.	1	50·00	1	50·00		
8 D. to 10 D.	1	50·00	1	50·00		

were free from astigmatism—and about which, therefore, there could be no ambiguity—are arranged according to the extent of the hypermetropia in their fixing eyes, and in it is shown

the relative frequency with which, through the successive degrees of optical defect, failure or improvement of either kind took place. Here, indeed, the proportion of such cases as were permanently improved was greatest among those whose refractive defect was least, and, throughout the three first classes, in which alone the numbers might be considered sufficient, declined as the defect increased. But if we take all the cases together, grouping them as in Table XLV B

TABLE XLV B (*all cases together*). *

Hypermetropia in lower meridian.	Improved with and without glasses.		Improved only when wearing glasses.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cen		per cent.		per cent.
Up to 2 D. .	13	61·90 (72·72)	5	23·80 (27·70)	3	14·28
2 D. to 4 D.	27	65·85 (71·05)	11	26·82 (28·94)	3	7·31
4 D. to 6 D.	8	42·10 (44·44)	10	52·63 (55·55)	1	5·26
6 D. to 8 D.	6	66·66	3	33·33		
8 D. to 10 D.	1	50·00	1	50·00		

according to the degree of hypermetropia in the lower meridians of the fixing eyes, the same decline is by no means so manifest, even if we put aside those which remained unaffected by the treatment. These, indeed, occurred most frequently where we should have least looked for

* The figures in brackets signify the proportions as they stand when the cases unaffected by glasses are left out of account.

them, that is, among the cases with a low degree of hypermetropic defect; and, on the other hand, permanent improvement took place even among those in whom the defect was greatest. So was it also with the cures, which, as will be seen from Table XLVI, were certainly distributed without much reference to the degree of hypermetropia that might be present. This, no doubt, seems anomalous, and especially so when we recall how close the relation between the degree of refractive defect and the extent of the convergence was found to be.* If the degree of ametropia determines the amount of the squint, and the extent of the latter is that which chiefly affects the possibility of cure, ought not this possibility to depend upon the degree of refractive defect? It certainly would do so but for the fact, to which we have just referred, of the participation of other influences besides hypermetropia in the production of convergent squint. The wearing of glasses can do nothing to neutralise these, it only interferes with the agency through which they work. We have no right, then, to expect that the results of our interference should necessarily depend upon the degree of the hypermetropia, for though the refractive defect may frequently be the only factor at work it may be backed up by other influences which cannot be touched by this method. It is, nevertheless, satisfactory to know that even with a high

* See above, p. 32, *et seq.*

Table XLVI.

Hypermetropia in lower meridian.	Cured with and without glasses.		Cured only when wearing glasses.		Improved but not cured.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
Up to 2 D.	2	9·52 per cent. (11·11 ,,)	2	9·52 per cent. (11·11 ,,)	14	66·66 per cent. (77·77 ,,)	3	14·28 per cent.
2 D. to 4 D.	5	12·19 ,, (13·15 ,,)	8	19·51 ,, (21·05 ,,)	25	60·97 ,, (65·78 ,,)	3	7·31 ,,
4 D. to 6 D.	3	15·78 ,, (16·66 ,,)	3	15·78 ,, (16·66 ,,)	12	63·15 ,, (66·66 ,,)	1	5·26 ,,
6 D. to 8 D.	1	11·11 ,,	2	22·22 ,,	6	66·66 ,,		
8 D. to 10 D.	1	50·00 ,,	1	50·00 ,,				

degree of ametropia not merely improvement but actual cure may be attained.

Difficulty has again to be faced when we consider the bearing which the age of the patient or the previous duration of the squint may exert upon the results to be obtained from spectacle treatment. The two factors in question, being so closely allied, may be conveniently taken together. Now the convergence, as we know, usually increases up to a certain limit determined by the conditions of each case the longer it remains untreated. Generally speaking, therefore, the greater the angle of the squint, the greater will have been the lapse of time since it first appeared. And as it was among those with the lower degrees of deviation that the use of glasses was most effectual, it would seem to follow that specially favourable results ought to be looked for in such patients as were of tender years, or had only lately become subject to strabismus. We have long been taught, moreover, that old-standing convergence brings about organic changes in the muscles of the deviating eye that must seriously hinder recovery by any other means than operation. It would not be difficult to find individual cases to confirm these suppositions, but our observations on a series of unselected instances give them no support. For on looking at the figures in Tables XLVII A and XLVII B, of which the first is concerned with the age and the second with the actual duration,

TABLE XLVII A.

Age at first visit.	Improved with and without glasses.		Improved only when wearing glasses.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cent.		per cent.		per cent.
Under 5 years	7	46·66	5	33·33	3	20·00
5 to 10 ,,	27	62·79	13	30·23	3	6·97
10 to 15 ,,	14	63·63	7	31·81	1	4·55
15 to 20 ,,	7	77·77	2	22·22		
Over 20 ,,	3	60·00	2	40·00		

TABLE XLVII B.

Duration before treatment.	Improved with and without glasses.		Improved only when wearing glasses.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cent.		per cent.		per cent.
Under 5 years	24	54·54	14	31·81	6	13·63
5 to 10 ,,	17	73·91	6	26·08		
10 to 15 ,,	12	80·00	3	20·00		
15 to 20 ,,	1	100·00				
Over 20 ,,	1	50·00	1	50·00		

we find that permanent improvement, so far from being specially associated with the younger or more recent cases, occurred least often among them, and tended to become more frequent in each succeeding period of life and each succeeding stage of duration. The cases also in which no improvement took place were among the youngest and latest established of the series.

Very similar was the state of things in respect of the cures. A larger proportion of these was found among the older than among the younger

patients, and among the cases of old standing than among those of recent origin (Tables XLVIII A and XLVIII B).*

There is another matter which cannot be disregarded, though it is not illustrated by the foregoing tables. This is the rate at which improvement took place. Explain it how we may, it is certainly the fact that among these cases improvement generally proceeded faster in those of longer than in those of shorter standing. So that the results, whatever they might be, were more quickly attained just where we should naturally have looked for most resistance.

All these circumstances appear anomalous enough, but it is nevertheless possible to find a reasonable explanation of them.

One simple cause for the comparative failure of the treatment in the case of very young children is the difficulty of applying it. The wearing of spectacles is sometimes disliked, and every opportunity taken of laying them aside. They are often broken and left unrepaired, and even when regularly worn, it may be in such a careless

* Messrs. Lang and Barrett (loc. cit.), taking ten years and under as a limit, found that not only were improvement and cure more frequent among the younger than among the elder patients, but that the reduction of the squint obtained a higher average degree among the former. Without attempting to explain away a serious discrepancy, it may be pointed out that though the method of treatment was the same, the two series of patients to which it was applied were not in all respects alike; and especially that their older cases apparently comprised several examples of alternation, which has here been dealt with by itself.

TABLE XLVIII A.

Age at first visit.	Cured with and without glasses.		Cured only when wearing glasses.		Improved but not cured.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
Under 5 years	1	6·66 per cent.	2	13·33 per cent.	9	60·00 per cent.	3	20·00 per cent.
5 to 10 ,,	5	11·62 ,,	7	16·27 ,,	28	65·11 ,,	3	6·97 ,,
10 to 15 ,,	2	9·09 ,,	6	27·27 ,,	13	59·09 ,,	1	4·54 ,,
15 to 20 ,,	1	11·11 ,,	1	11·11 ,,	7	77·77 ,,		
Over 20 ,,	—	—	1	20·00 ,,	4	80·00 ,,		

TABLE XLVIII B.

Duration before treatment.	Cured with and without glasses.		Cured only when wearing glasses.		Improved but not cured.		Not improved, or deteriorated.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.	No.	Proportion.
Under 5 years	5	11·36 per cent.	9	20·45 per cent.	24	54·54 per cent.	6	13·63 per cent.
5 to 10 ,,	3	13·04 ,,	3	13·04 ,,	17	73·91 ,,		
10 to 15 ,,	4	26·66 ,,	2	13·33 ,,	9	60·00 ,,		
15 to 20 ,,	—	—	—	—	1	100·00 ,,		
Over 20 ,,	—	—	—	—	2	100·00 ,,		

fashion that little good can be expected to follow. Hence there is nothing surprising in the fact that in patients under five years of age cure or permanent improvement is somewhat difficult of attainment.

But something more is required to explain how it is that, after the limit we have named is passed and until adult life is reached, the advantage should still rest with the elder rather than with the younger patients. This we believe to be the diminution in the range of accommodation as life advances. Every young child, as we know, has at his disposal a large amount of accommodative power. If he be hypermetropic, part of this is constantly being employed to neutralise his defect, and he is unable voluntarily to relax the strain upon it. With the onset of squint, the habit of over-exerting the ciliary muscles will become still more pronounced, for the accommodation, having been relieved from the necessity of adapting itself to the requirements of binocular vision, will be left to work uncontrolled, and its natural action will be thereby exaggerated. Now the instillation of atropine at the beginning of treatment of course makes all accommodative effort for the time impossible, and when this measure is followed by the adaptation of fully correcting glasses, the chief stimulus to excessive action of the ciliary muscles is permanently removed. But there will still remain the habit of constant exertion of

those muscles, a habit which will reassert itself when the effects of atropine have passed away, and will be the more difficult to overcome because of the large amount of accommodative power naturally possessed by the patient, the employment of which, whether necessary or not, has now been made so much easier to him. It is not to be expected therefore, that, in such a state of things, the use of glasses will produce a very rapid or extensive effect upon the associated convergence. As the patient grows older, however, his range of accommodation will decline, he will learn also to adjust the efforts of his ciliary muscles more exactly to the work required of them, he will be as economical as he can of the power at his disposal. It is then that the correcting lenses will be most beneficial. The relief given by them to the accommodation, will be not partial but complete, and with the strain upon that function will disappear also the necessity for abnormal convergence. The squint will thus be reduced more rapidly than at the earlier age, and, if not of too great extent, may be abolished altogether.

These two factors, then, seem to explain fairly enough, firstly, the poor results obtained in children under five years of age; secondly, the greater frequency with which permanent improvement is effected as the age increases up to adult life; thirdly, the quicker rate of improvement that attends advancing years until the same

limit is reached. They suggest also that the organic changes which have been referred to do not come about, as a rule, before the twenty-first year, though it is very likely that they may, after that period, form the chief obstacle to a cure by this method.

The results of spectacle treatment do not seem to have been much affected by the earlier or later period at which the strabismus first appeared. It is true that all but one of the cases in which no good was effected began to squint before the end of their fifth year; but, on the other hand, among the many in which satisfactory results were obtained permanent improvement or cure came about with nearly equal frequency whether the convergence first showed itself during or after the first five years of life, so that the period of onset may be regarded as a minor element in the matter.

Something must be said, lastly, as to the duration of the treatment. *Cæteris paribus*, of course, the longer the spectacles are worn, the greater should be their effect in diminishing the squint; but then we can never be sure that any two given cases are in all respects alike, and some single circumstance, quite unknown to us, may be enough to determine a better or quicker result in the one than in the other. And if we compare whole groups of cases, as in Table XXXIX,* we find that it is by no means those that are sub-

* See above, p. 121.

mitted to the longest course of treatment that experience the greatest benefit. The final result, in fact, is determined not by the length of time that the treatment is carried on, but by the special conditions of each individual case. And for each case, as we have seen above, there is a limit beyond which the glasses are unable to reduce the convergence. We have to watch for the time when their full effect shall have been produced, but it is not possible for us to predict, even approximately, when that time will come.

Summing up, then, the results of spectacle treatment in monocular convergent strabismus as exemplified by these cases, we find—

i. That by this method permanent reduction of the convergence was brought about in more than 60 per cent. of all the patients; that in about 30 per cent. the squint was diminished so long as the glasses were in use; that in less than 8 per cent. there was no improvement whatever;

ii. That this improvement extended as far as complete cure, independently of the further use of the glasses, in about 13 per cent., and subject thereto in a further 17 per cent. of the whole number; that benefit short of cure was obtained in nearly 62 per cent., the remainder being those upon whom no effect was produced.

With respect to the conditions under which improvement took place, we note—

i. That much depended upon the amount of convergence existing when treatment was begun, for whilst good results followed even in extreme degrees of squint, actual cure was brought about only when it was originally of moderate extent;

ii. That permanent improvement or cure was possible whatever the degree of refractive defect might be, no special advantage being associated with the lower degrees of hypermetropia;

iii. That good results were more frequently and more rapidly obtained as the age increased from infancy up to the end of the twentieth year, improvement being hindered by the difficulty of applying the treatment and by the excess of accommodative power in the earlier periods of life and by organic muscular changes in the later;

iv. That the results were little affected by the time of life at which the squint appeared;

v. That the extent of the benefit was not proportionate to the time the treatment lasted, the period of which the maximum effect was obtained depending upon the special conditions of the individual patient.

But there remain the cases in which the treatment brought about no improvement, or

was even accompanied by an increase in the convergence. It is true that they were but seven in number out of a total of ninety-four, a proportion of 7·44 per cent., but it is impossible to ignore them, or merely dismiss them as the product of accidental circumstances. For whether the proportion of failures should be greater or smaller in a larger range of cases than the present, it is certain that we must be prepared to meet with such in dealing with any substantial number of patients.

Now in looking at each of the present examples in turn, it is not easy to find any special bond of connection between them. One might seem to have failed through carelessness in the use of the spectacles, another by reason of its subjection to strong hereditary influence, whilst others showed no unusual characteristics whatever. It is indeed only by grouping them all together, and noting their general features, that we can form any opinion as to the reasons why they, out of so many, should have failed to respond to the treatment.

This has been done in the last few tables,* where they are placed side by side with the others, and we arrive thereby at the following results. We find, to begin with, that the cases in question exhibited but a moderate degree of convergence, one only out of the seven suffering from a squint of over 20°, whilst the average deviation throughout was no more than 17·14°.

* Tables XLII to XLVIII, pp. 125—136.

In the next place, the refractive defect was of no great amount. For though in a single instance, the hypermetropia of the fixing eye was as much as 5 D., yet the average degree for all the fixing eyes together did not exceed 2·5 D. Thirdly, they were generally of tender age when they first came under treatment, only two of them having passed their seventh year, and the majority being still far short thereof. As a correlative to this, the squint had been present in nearly all for a comparatively short time.* Finally, though the vision could not be ascertained in the first instance in five out of the seven because they were too young, yet observations made at a later period when they could all be examined on this point, showed that the relative amblyopia in no case attained more than a moderate degree.†

What inference, then, are we to draw from all these circumstances? Surely it must be that we have here a group of those cases of which we have already spoken as standing midway between the ordinary monocular and the alternating type. They resemble the former in that their deviation

* See Table XLVII, p. 134.

† Those who believe in the possibility of substantial improvement in the vision of a squinting eye would scarcely look for it in cases where the convergence, in spite of spectacles, had remained stationary or grown worse. On the other hand, if amblyopia from "suppression" be a reality one would expect it to have been far more pronounced than it actually was in these patients. The visual defect, as we hold, remained the same from first to last.

is always manifested by the same eye, and that they show defects of vision and of refraction; but they are allied to the latter in that their defects are of low degree and insufficient of themselves to induce strabismus. It seems probable, therefore, that in these cases the deviation was provoked by one or other of those reflex nervous disturbances in which it was suggested above that the origin of alternating squint might be found. One of them, at any rate, alternated at first, two others had suffered from disorders which frequently arouse disturbance of the nervous centres. If such causes brought about the deviation, it is not difficult to understand why the employment of correcting glasses should remain without effect. Even when their use was followed by diminution of the convergence, the extent of such diminution was not regulated by the degree of hypermetropia; that is, by the degree of relief given to the accommodation, a state of things we explained as probably due to other factors besides accommodative strain frequently participating in the development of the squint. If then, as we hold was the case here, such other factors were alone responsible for the appearance of strabismus, it is obvious that correction of slightly faulty optical conditions would be powerless to restore the eyes to their normal position. The complete failure to obtain any improvement seems thus to be naturally accounted for, though the difficulties attending the use of

spectacles by young children doubtless had something to do with the matter.

B. From what has been said above it will be surmised that no very satisfactory results were obtained in the case of patients with alternating convergent strabismus. Such indeed was the fact, for though the treatment was not entirely without effect, yet it was attended as a rule by only a limited degree of benefit.

In eight of the twelve patients whose general conditions we examined in Section V, it was possible to ascertain the results which followed the regular use of fully correcting glasses. The number is small, but it is sufficient to give us some idea of how a larger series would probably

TABLE XLIX.

Cases ranged according to the degree of improvement effected.	No.	Proportion.	Average length of treatment.
		per cent.	
Improved both with and without glasses	3	37·50	12·66 months.
Improved only when wearing glasses	4	50·00	9·50 ,,
Not improved, or deteriorated	1	12·50	8·00 ,,

behave under similar treatment. Table XLIX shows how far these alternating cases were affected by spectacles just as Table XXXIX* did for the monolateral variety, and the two should be compared together. Here the ratio of those permanently improved was under 40, but in the

* See above, p. 121.

former case over 60 per cent. There the proportion of those that showed no improvement when the glasses were off was less than one third, here it was as much as half the total number. Of the monolateral cases no more than 7·44 per cent. remained unaffected, of the alternating as many as 12·50 per cent. So, too, in respect of the cures, for Table L compared with Table XL* demonstrates that these were less common among the alternating than among the monolateral cases. In the latter 30 per cent., but in the former only 12·50 per cent., were relieved of their deformity

TABLE L.

Cases ranged according to the degree of cure effected.	No.	Proportion.	Average length of treatment.
		per cent.	
Cured both with and without glasses	1	12·50	14·00 months.
Cured only when wearing glasses	0		
Improved, but not cured .	6	75·00	10·33 „
Not improved, or deteriorated .	1	12·50	8·00 „

by the use of glasses. Even assuming the possibility that, with increased numbers, the contrast between the two kinds of squint might be less marked than it appears in our series, it seems sufficiently clear that the alternating form is far less amenable than the monolateral to this method of treatment.

In the last two tables, however, is given the

* See above, p. 122.

average length of time for which each group of cases was under treatment, and there will at once be noticed an apparent correspondence between the extent of the improvement and the time employed to bring it about. Where the improvement was permanent the spectacles had been worn for more than a year; but where it was only temporary for less than ten months; where, finally, no benefit at all resulted, their use had been persisted in for no longer than eight months (Table XLIX). Upon the single case that was cured fourteen months were spent. Upon the six improved but not cured an average period of ten months (Table L). We are tempted, then, to infer that time was here a matter of much importance, and that with a little more patience the deformity of these cases might have been yet further reduced—more cures possibly have been effected. But we cannot accept such a conclusion. In the first place it would not accord with that which we arrived at in dealing with the monolateral variety,* when we found that the mere prolongation of the treatment did not necessarily involve a corresponding reduction of the squint. Yet there the correction of refractive defect was a matter of primary importance; it would be strange if here, where it can play only a secondary part, it should bring about more exact results. Then, again, the differences in time are not great enough to account for the

* See above, p. 139, *et seq.*

varying measure of success obtained. If glasses could be worn for more than nine months and yet bring about no permanent diminution of the squint, is it to be supposed that persistence for a further three months would have had that effect; or that, after eight months had elapsed without result, another six weeks would have sufficed to turn failure into partial success? Another fact also may be pointed out which is not shown by the tables, but which should be taken into consideration. This is the limited extent of the improvement effected in the middle group of cases —that in which the squint was diminished, but only whilst the glasses were being worn. Though the average period for which they were in use was nine and a half months, in no individual was the convergence lessened by more than 6°, the average reduction being 5·25°. In the corresponding class of monolateral cases several instances occurred where the improvement went no further than here, but the average reduction was far greater, amounting to as much as 10·72°, a circumstance which of itself shows pretty clearly the relative effect of glasses in these two varieties of squint. From a practical point of view, cases in which the deviation cannot, after prolonged trial, be diminished by more than 6°, and then only whilst the spectacles are actually being worn, must be looked on as failures, so that the proportion of our alternating patients that remained unimproved should be taken as being not 12·50

but 62·50 per cent., that is to say, nearly two-thirds of the whole number.

We have, in truth, to recognise the fact that in alternating squint the correction of refractive error does little in most cases towards reducing the convergence; nor is there any reason for surprise at this when we remember how slight is the degree of optical defect that usually accompanies this variety of strabismus. Hypermetropia is here, not a predominant, but a subordinate factor, and its neutralisation therefore cannot be expected to do much towards removing a deformity which owes its origin to the action of other causes. Now and then, indeed, the use of glasses is found to be beneficial, but this only in a minority of cases, where, for one reason or another, the influence of the hypermetropia has not been entirely unfelt.

Hence it is clear that the prolonged wearing of spectacles cannot greatly affect the ultimate result. The improvement to be got from them is limited, and no long period is required to show how far it will go. It is an accidental circumstance that in the patients we are dealing with the advantages gained should seem to have depended to some extent on the length of time the glasses were worn. In reality, a fair trial was here made of the treatment; it was not continued further because it had produced its full effect, and the cases showed themselves to be ripe for operation.

Our conclusion, then, is that glasses are of no

great use in most cases of alternating squint, for the reason that this form of strabismus is so largely independent of local conditions. But we have to remember also that some few patients can be substantially and permanently benefited by them, and that through them even cure may occasionally be brought about.

Having now before us the results of spectacle treatment as exemplified in these two series of cases, it is possible for us to formulate with some precision the general principles which should be followed in dealing with convergent strabismus, whether monolateral or alternating.

At the outset, then, we hold it to be a matter of primary importance that in every case in which their regular use can be depended on, fully correcting lenses should be prescribed as soon as possible after squint has made its appearance.

But the regular use of spectacles is very far from being always practicable. For on the one hand the convergence often enough shows itself in the very earliest stages of life. In 40 per cent. of our monolateral cases it certainly appeared before the end of the third year.* Yet even when patients of such tender age are brought for treatment it is of little use to order glasses for them. Not till the fourth year has been reached can an ordinary child be expected to tolerate spectacles, or at any rate to wear

* See Table III, p. 11.

them in such a way as to derive material benefit from them. As a matter of fact, however, in a very small proportion of cases—it was less than 5 per cent. in our monolateral series—is advice asked for on behalf of children under four years of age. Squint may have developed, but is neglected, usually in the hope, so very rarely justified, that "it will come right of itself in time." Not only, therefore, is this method of treatment difficult of application in the case of very young patients, but in far the larger number of such the mere opportunity of trying it is withheld. On the other hand we may frequently be met by strong reluctance, or even absolute refusal, on the part of a patient who is nearly grown up to submit to the constant wearing of glasses. For near work their assistance may be welcomed, but for any other purpose rejected. It is useless, under such circumstances, to attempt a procedure which we cannot be sure will be properly carried out, and we must resort to whatever operation seems best adapted to the particular case. Little need be said as to those who have actually reached maturity. Few such desire treatment at all, and though spectacles may be submitted to and afford some advantage, their employment is of far less importance than in earlier life.

The conditions just mentioned are the only ones limiting the prescription of glasses in convergent strabismus. That is to say, that for patients of every age, from about the end of the

third year to the approach of adult life, spectacles fully correcting all refractive error should in the first instance be ordered, and their regular use insisted on. Whether the squint be monolateral or alternating, constant or periodical; whether it be of old standing or recent, of extreme degree or barely perceptible, this is what ought to be done before anything else is thought of.

But if such a measure be adopted as a matter of rule, we ought to have some definite ideas as to the length of time it should be persisted in. On this point our decision must in each case be based upon two considerations,—the one being the effect produced, the other the age of the patient. It is clear that as long as the wearing of glasses is accompanied by a progressive diminution of the squint, it is undesirable to do anything further. The rate of progress varies, indeed, not only as between different patients, but in the same individual; yet so long as any benefit at all is being obtained by a method that cannot possibly do harm, we should be reluctant to change it for another, which, however, immediately successful, may in the end bring about very mischievous effects. We do not mean to say that operative measures are absolutely precluded because improvement may still be expected from the use of glasses, but the cases are relatively few in which, under such circumstances, it is safe to employ them. Sooner or later, however, the full results of spectacle treatment will be attained,

and then, but as a general rule not till then, should operation be resorted to. More especially ought patience to be shown in dealing with children of tender years. Improvement in them is often slow in coming, more slow generally than in older cases; the command of the muscles is less perfect; the disfigurement a matter of less importance; the results of operative interference more uncertain. This last point, indeed, is now so far recognised that many surgeons hesitate to operate on any patient who has not passed his tenth year. We should be inclined to place the limit still later, and to say that only in exceptional circumstances should anyone be operated on for squint before he has passed his twelfth year. It is certain in any that the younger a patient is the greater will be the risk of seeing operative interference followed by unfortunate consequences. We should say, then, that in patients under twelve years of age, spectacles ought alone to be relied on as long as these seem, by examination at regular intervals, to be reducing the squint; and that operation should be resorted to only when they are found to be no longer doing so, or to have been from the first ineffectual. By those also who have passed their twelfth year spectacles should be worn as long as any good can be got from them; but if the convergence does not yield readily to their influence, and is besides of such a degree that cure can scarcely be expected from them

alone, then an operation may be performed. Considerable care must be taken, however, lest the incautious use of glasses after operation should bring about divergence. Since the final effect of an operation is usually less than the primary, the safest course is to discontinue the spectacles for distant vision until the parallelism which has been established is beginning to change again to convergence. Their resumption then for constant use will be of the utmost service.

We have yet to consider how those should be dealt with who cannot, or will not, submit to the constant wearing of glasses. Here again, it is the age which must determine our decision. During the first three years of life the prescription of spectacles is, for obvious reasons, out of the question, and we have to fall back upon something else. Anything in the way of operation is, however, quite inadmissible. Whoever has seen the disastrous results which may follow a tenotomy performed at this early age can have no hesitation in pronouncing any such procedure unjustifiable. But if glasses cannot and operation may not be employed, our choice must lie between leaving things alone and using atropine. The objections to the latter are serious, for the drug has to be used continuously over a long space of time, and the discomfort it causes cannot be obviated. Yet when a squint is progressive this is the only means of checking its increase, and it should be adopted in preference to letting matters take

their own course. If, however, the convergence be slight and practically stationary, it is better not to interfere at all, but to wait for the time when spectacles can be properly worn. When that period has arrived it is rare indeed for the aid of glasses to be rejected. The difficulty usually is to secure their being worn in such a way as to be beneficial,—a difficulty which becomes less as the patient grows older. Still, cases occur in which an operation is desired, without any preliminary treatment, and before a safe age has been reached. The only rule that can be laid down for such is to do too little rather than too much. It will be far better to leave some convergence uncorrected than to run the risk of inducing any divergence. Neither is it possible to fix exactly what is the earliest age at which an operation may be performed under these circumstances, for proceedings which might be permissible in a young patient with 30° of convergence would be out of the question in another of the same age who exhibited only half that amount. Each case, in fact, must be considered on its merits, and where there is any reasonable doubt as to the consequences of an operation, all interference should be postponed. For, however seldom it may come about, the possibility of spontaneous cure must always be borne in mind. The advisability of primary operation on patients of more advanced years has already been discussed, and need not be referred to further.

We have only to add here that the results of spectacle treatment show that, whether at the earlier or the later period of life, there is far less occasion to hesitate about operating where alternating squint is concerned, than when we are dealing with the monolateral variety.

To recapitulate; our general rule is that glasses, fully correcting all refractive error, should be ordered in the first instance for every patient with convergent strabismus whose age lies between the third and the twenty-first year and who can be induced to wear them regularly.

During the first period of life, when spectacles cannot be used, the convergence, if slight may be left alone ; if considerable, should be treated with atropine. But no operation is permissible at this time.

Later on, that is, from the end of the third to the end of the twelfth year, spectacles ought to be almost exclusively relied on. Operation may be resorted to, however—

i. When the glasses are found to be of no benefit from the first;

ii. When they have produced their full effect, and the squint is stationary short of cure;

iii. When their use is absolutely rejected.

In this last case interference should be postponed as long as possible, and should rather fall short of than exceed what is apparently required, since—

i. Spontaneous cure may come about;
ii. Subsequent divergence is to be feared.

In the third period, from the beginning of the thirteenth to the end of the twentieth year, spectacles ought to be used at first and their final effect waited for, but operative proceedings may be undertaken sooner if ultimate cure appears unattainable by glasses alone. Primary operation also, which will be more frequently desired, is less likely to produce ill effects than at an earlier age, though some care must be exercised in practising it.

For the few patients who come for treatment in adult life, immediate operation is usually the only course possible.

The treatment of alternating differs from that of monolateral squint chiefly in the comparative inefficacy of glasses, and in the consequent necessity of an earlier resort to operation.

We have insisted strongly on the necessity for spectacles in every case of convergent squint where they can and will be worn, and have also indicated the conditions under which some kind of operative interference is called for.

In point of theory it would seem that every patient whose deformity has not been entirely removed by glasses, ought to be subjected to an operation in order to bring about the desired result. According to our own tables this would seem to imply that about 70 per cent. of those

with monolateral and nearly 90 per cent. of those with alternating squint require to be dealt with by operation in spite of previous spectacle treatment.* There may be those who would argue from such figures that if operation is, after all, so frequently necessary, it ought to be undertaken at the very first, and its effects supplemented, and not anticipated, by the troublesome spectacle method. We do not intend to go over the whole question again; it is quite enough now to point out that even if glasses brought about cure far less often than they actually do, yet substantial improvement follows their use in the great majority of cases, and that for each case so improved the severity of any future operation is proportionately diminished.

But, as a matter of fact, the proportion of monolateral cases at least, in which, after the wearing of glasses, operation is required, certainly falls far short of 70 per cent. Out of our ninety-four patients with monolateral squint, twenty-six were actually operated on, whilst for twelve more operation was recommended but declined; these thirty-eight representing 40·42 per cent. of the whole number. There were, then, twenty-nine patients cured by glasses only, and thirty-eight to whom operation was applicable; how are the remaining twenty-seven, who formed a proportion of 28·74 per cent. of the total, to be accounted for? Detailed examination shows that they fell

* See Table XL, p. 122, and Table L, p. 146.

into two groups; an elder, whose average age was something over sixteen years, and a younger with an average age of rather less than seven years. In the former of these the convergence, by means of glasses, had been brought down to 8° or less, or, to put it more exactly, to an average of 5·66°; so that, though no further improvement was to be expected, the propriety of trying anything else was at least doubtful. Whether we can undertake to interfere in such circumstances, and if so, by what method, we shall consider later; but it is certain that the ordinary modes of operating are unsuitable, and that, as a rule, nothing is done when the squint is so insignificant in degree. In the second and younger group the average convergence was 9·39°, and it is clear that in time some of its members might be cured, whilst others would probably have to be operated on, a residue being left in a position similar to that of the members of the previous group. If we are to recognise the existence of a class of cases for which, though some convergence be still left, any kind of operative proceeding is to be regarded as unsuitable, we cannot be far wrong in concluding that not more than about one half of the patients with monolateral squint will, after the consistent use of spectacles, require to be dealt with by operation.*

* Of course, if those be reckoned in who ask for immediate operation without preliminary spectacle treatment, the proportion would stand somewhat higher.

It is otherwise with the alternating cases. They are little amenable to the influence of glasses, and it is therefore necessary to operate upon a very large proportion of them. In illustration of this we may point out that in seven of our eight patients, that is in 87·50 per cent., some operation was required, and we may fairly doubt whether, in dealing with a much greater number of cases, the necessity for operative interference would turn out to be anything less frequent that it was here.

When, however, we have decided to operate, how are we to be guided in our choice of operation? Clearly the most important factor in the matter must be the degree of the convergence that has to be corrected. But it is not the only one; for we have to take into account whether glasses have been previously worn, and what their effect has been, and whether, if necessary, they could be used subsequently. Further, the relative power of the ocular muscles must be noted, and especially the extent to which abduction of the deviating eye is possible. Our aim, we must remember, is to rectify the position of the deviating eye, to bring the visual axes of the two eyes parallel to each other in distant vision; and we hold that this should be accomplished at once, and that in almost every case no more and no less than this should be done. Our patients, with rare exceptions, should leave our hands after a single operation showing neither divergence nor convergence.

Now, with whatever variety of detail, the operative proceedings open to us in convergent strabismus are ultimately two, tenotomy of the rectus internus, and advancement of the rectus externus, the latter hitherto employed in this country only in combination with the former. We may, then, perform a simple tenotomy of one internal muscle, or we may do this and increase the effect by advancement of its opponent. Further, we may divide both recti interni, either simultaneously or after an interval, and, if necessary, supplement this procedure by bringing forward one of the externi.

We require, then, to know what is likely to be the effect of each of these various operations. And first as to that of a simple subconjunctival tenotomy of the rectus internus. This was performed as a primary measure upon twenty-two of the present series of cases, being followed in three of these by some subsequent proceeding. Glasses had been worn in every case, and in every case their use was continued immediately

TABLE LI.

Average original degree of convergence.	Average length of spectacle treatment.	Average age at time of operation.	Average convergence before operation.		Average convergence just after operation.		Final average convergence.	
			Without glasses.	With glasses.	Without glasses.	With glasses.	Without glasses.	With glasses.
27·59°	months. 17·63	years. 12·36	25·72°	17·72°	10·84°	5·28°	11·53°	5·23°

after the operation. Table LI gives the results. It will be seen that the average degree of convergence present before any treatment was applied was 27·59°, and that by the employment of spectacles this had been brought down to an average of 17·72° at the time of operation. The greatest extent of squint dealt with was 26°, the least 8°. The average convergence within a week of the operation was 5·28 with the glasses, the reduction in the squint therefore amounting with their assistance to 12·44°. A month or more after the operation the convergence exhibited whilst the spectacles were on was 5·23°, so that the final reduction effected by tenotomy supplemented by the use of glasses was 12·49°. This amount falls a little short of the average obtained in other series.* Of course, with a vigorous external rectus a far greater result than this may follow, and a convergence of 25° or more may be completely removed. But in ordinary circumstances we may take it that simple tenotomy will suffice to cure a squint which does not exceed 15°.

Now it is usually the case that—spectacles apart—the final effect of a tenotomy is rather less than the immediate, owing to the internal

* The cases analysed by Messrs. Lang and Barrett give an average final reduction of 14·7 ('Roy. Lond. Ophthal. Hosp. Reps.,' 1896, vol. ii, p. 15), and those by Dr. Maxwell ('British Medical Journal,' 1896, vol. ii, p. 818) exactly the same for distant vision. It is not stated whether, in the latter series, glasses had been worn since the operation.

rectus, after its tendon has again become firmly attached, regaining some of its former predominance. Is it possible to judge whether and how far the use of glasses counteracts this tendency? To some degree we believe it is. In six of our cases the convergence ultimately increased, but the average increase was no more than 2·66°. Six other cases, on the contrary, improved, and their average improvement amounted to 6·16°. So that the influence of glasses is by no means at an end, though an operation be required. In the ordinary course of things the squint of most of these twenty-two patients would have eventually been greater than directly after tenotomy was done, yet it was only in six instances that this happened; in the rest the effect of the operation was maintained or increased. One patient, indeed, showed a tendency to divergence which was at once checked by leaving off the spectacles.

Simple tenotomy, however, does not always suffice to remove the squint, even when glasses have been previously worn, so that we have to supplement it by some further proceeding. Assuming that convergence of 12° or more is left, what ought then to be done? The easiest thing is to divide at once the tendon of the internal rectus of the fixing eye. This double operation rests on a scientific basis—that of the equal distribution of the convergence effort

between the two recti interni—and it is simple, rapid, and usually effectual.* It was performed on two patients of our series, both of whom had worn glasses for some time, and still showed a deviation of more than 30°. In each case the cure was complete, nor was any ill effect to be seen in either several weeks afterwards.† The advantages of the operation are therefore great, but there is nevertheless some risk attaching to it, because the two recti externi are left without any opposition and ultimate divergence may result. This risk, which is greater in the earlier years of life, may be much diminished by doing the second tenotomy at such an interval after the first as may allow the one tendon to become re-attached before the other is interfered with. The procedure was successfully adopted in three of the present cases whose average squint had been reduced by glasses from 38° to 24°, and by a first tenotomy from 24° to 15°.‡ The postponement, however, involves two operations where one ought to be enough, and in any case

* The proceeding was first suggested and practised by the late Dr. E. W. Duffin, and marked a conspicuous advance in the operative treatment of squint. It had previously been the custom, in dealing with cases of pronounced convergence, to divide freely not merely the tendon but the conjunctiva and capsule of Tenon of the deviating eye, a method fruitful in the production of divergent and bulging eyes.

† One of these patients was thirteen, the other seventeen years of age.

‡ The average age at the time of the first operation was 11·33 years.

the double operation diminishes the mechanical power over the ocular movements which it should be our object as far as possible to preserve.

When, therefore, a single tenotomy does not of itself abolish the squint, it is often better to do something to increase the power of the external rectus of the deviating eye than to resort to tenotomy of the internal rectus of its fellow. This is effected, of course, by advancement of the muscle in question, either with or without division of its tendon.* We may admit that the proceeding, the details of which need not be given here, is tedious and troublesome. A more important thing to know is what advantages it offers. Without any doubt the chief one is this,—that by their means we can be sure in nearly every case of obtaining at once the result we desire. A single tenotomy, for instance, may leave a deviation of 8° and 10° still remaining,—an amount small enough to make the performance of a second one on the other eye somewhat hazardous. But by combining capsular advancement of the external with tenotomy of the internal rectus of the deviating eye, the whole of the convergence may be effectually and safely removed. So, again, double tenotomy may not

* The "capsular advancement" of De Wecker is a modification of this operation, and consists in separating from the muscle the closely attached overlying portion of Tenon's capsule and tightening this by a suture. The indirect capsular attachment of the muscle is thus strengthened whilst the direct tendinous one is not interfered with ('Annales d'Oculistique,' vol. xc, p. 189).

be sufficient to rectify an excessive deviation, but a single tenotomy, supplemented by advancement of the opposing tendon, will generally do so. And should parallelism not be brought about by these proceedings we are still at liberty to deal later on with the untouched fixing eye. Our results can thus be calculated with greater precision and produced with the least possible loss of mechanical power.

However, to advocate one mode of procedure is not to exclude the other, where both have their own advantages, and the choice of either must be determined by the special circumstances of each case.

Our object, we have said, is to abolish all convergence at once. But since the ultimate effect of an operation is usually less than the immediate, it would seem as if we ought to try to bring about divergence in the first instance rather than exact parallelism, so that the final result may be what we wish.* But it must be remembered that if a permanent divergence be the consequence of our interference, our only way to remedy it is by a second operation; whereas, on the contrary, not only may parallelism be maintained, but some degree of convergence corrected by the use of glasses after the first operation. Hence there can be no necessity for producing divergence, except where the help of glasses is

* See "Precision in Squint Operations," by Dr. Patrick W. Maxwell, 'British Medical Journal,' 1896, vol. ii, p. 818.

sure to be rejected. And if the operation which has been determined on turns out to be somewhat insufficient for its purpose, it is far safer to rest satisfied with an incomplete result and trust to spectacles to supply what is wanting than to risk disaster by doing more than is required.

One other point has yet to be considered. Supposing that the final effect of glasses, or of operation followed by glasses, is to leave convergence of some 8° or less still remaining, ought anything further to be done? Such a deviation, though slight, may be great enough to be noticeable; it will certainly be great enough to prevent the establishment of binocular vision. Yet a single tenotomy has hitherto been the least operation available, and, as its average effect exceeds the amount of convergence in question, there must be a real risk of divergence following its performance. The usual course, therefore, has been to leave squint of such low degree alone. This is scarcely necessary in every case, for though under ordinary circumstances tenotomy is not applicable to a deviation of less than 12°, yet it may be used to remedy one of no greater extent than 8°, provided that vision is fairly good in the squinting eye, that the patient has passed childhood, and that some power of supervision can be exercised afterwards. In such cases it will be prudent also to lay aside the glasses for a time. But tenotomy certainly ought not to be done upon any eye which shows less than 8° of

convergence. Is there, then, nothing more that we can do when a squint has been reduced below this limit? If our resources are at an end a certain number of patients must resign themselves to permanent deformity and, even though both eyes be possessed of good vision, give up hope of ever being able to use them together. The remedy must clearly be the adoption of some operative procedure other than those already discussed. Such a procedure we believe to be that which has been strongly advocated and for many years practised by Dr. Landolt, but which has not, as yet, won acceptance in this country—the advancement of the external muscle without tenotomy of its opponent. It is true that it is recommended as a general substitute for tenotomy, but its comparative difficulty of performance will probably be enough to hinder for a long time its substitution for the older and easier operation.* Yet even if it should never succeed in displacing tenotomy as our first operative resource, there seems to be no reason why it should not be employed to a more limited extent; and should its

* Dr. Landolt's procedure is carefully graduated according to the effect required, and ranges, in cases of convergent strabismus, from advancement of one externus without resection of the tendon and without tenotomy of its antagonist, up to resection and advancement of both externi, supplemented by tenotomy of an internus (British Medical Journal,' 1896, vol. ii, p. 821). In a letter to the present writer Dr. Landolt says :—"In fact tenotomy has become a rare operation in my practice, though we are sometimes obliged to recur to it in very high degrees of squint of long standing."

use in the class of cases we are dealing with be justified by experience, complete cure, so far as the deformity is concerned, will be attainable in every case of convergent squint.

We may summarise, then, in general terms as follows :

The choice of operation must be determined by—

i. The degree of convergence present ;
ii. The power of abduction of the deviating eye;
iii. The previous effect of glasses and the possibility of using them subsequently.

I. Where the deviation amounts to 12° or more, tenotomy should first be done, and its immediate effect noted.

i. If there should then be left a convergence of 5° or less, glasses should be relied on to effect a complete cure.
ii. If the result be to leave from 5° to 12° of squint, rectification should be brought about by immediate "capsular advancement."
iii. If the convergence remaining exceed 12°, either immediate advancement of the external rectus should be done or tenotomy of the internal rectus of the fixing eye be performed later on. The former proceeding is preferable where there is feeble abduction of the deviating eye.

II. In cases where the convergence before

operation is not less than 8° nor more than 12°, tenotomy may be employed, provided that—

i. Vision is fairly good in the deviating eye;

ii. The patient is past childhood;

iii. Subsequent supervision can be exercised.

III. Where the squint is less than 8° the choice lies between doing nothing and advancing the external without dividing the internal rectus.

In performing any operation absolute immediate rectification should be aimed at; to bring about divergence is only permissible when the subsequent use of glasses cannot be relied on.

Now, assuming that by operation or otherwise we have succeeded in our primary object, and have entirely removed a patient's squint, are we to look upon our task as then at an end? As a general rule we certainly must, because nothing further is expected or desired. Yet there will still exist in the great majority of cases a serious visual deficiency in the once deviating eye, nor will binocular vision come about as a matter of course. It is clearly desirable that these deficiencies should be made good if possible, and we ought to know, therefore, what we can do towards that object.

It has been already admitted that improvement of the vision of the squinting eye may, and sometimes does, take place after its position has been rectified. Such improvement, of course, means not only that the vision of that eye is more acute

than before, but that it is more nearly on a level with that of its fellow. It is necessary to remember this, because in a certain number of cases the vision of the fixing eye falls below the normal standard,* and therefore a moderate increase in the visual acuteness of a once deviating eye, though still leaving a serious deficiency, might yet imply a considerable decrease of relative amblyopia. But, in any case, the matter is one not very easy to investigate, especially where young patients are concerned, and it is necessary to make full allowance for slight variations due to accidental changes in the conditions under which examination is made. Improvement, to be really counted as such, should be distinct and permanent. Tried by such a standard, what proportion of formerly squinting eyes can be expected to improve? Now, in thirty-seven of those patients belonging to the present series, it was possible to note the state of the vision some time afterwards; and it appears from Table LII

TABLE LII.

Vision of rectified eye.	Monocular cases.		Alternating cases.		All cases together.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cent.		per cent.		per cent.
Vision improved . .	6	18·18	1	25·00	7	18·91
,, not improved .	25	75·75	1	25·00	26	70·27
,, always equal .	2	6·06	2	50·00	4	10·81

* See Table XXVII, p. 77.

that, taking alternating and monolateral cases together, nearly 19 per cent. showed some improvement. That is to say, the vision of the eye that used to squint was more nearly equal to that of its fellow, besides being absolutely better. Of the rest a large number, being more than 70 per cent. of the whole, underwent no improvement; whilst a few, who formed 10·81 per cent. of the total, could not manifest any change, inasmuch as the vision of the two eyes was the same throughout.

A modest proportion, then, of eyes that have squinted may be expected to see better after their position has been rectified than they did before. This change we believe to be the effect of an unconscious education under new and more favourable conditions. But we may note that of the six monocular cases one only improved, so far as to attain equality of vision in the two eyes, and that occurred where the formerly squinting eye was possessed from the first of a high degree of visual capacity. All the others still manifested some relative amblyopia. That is to say, the increase in visual acuteness could not be carried beyond a certain limit, and this could only be because of a congenital incapacity on the part of these eyes for further improvement. If their vision was depreciated merely through disuse, it ought to have been possible to restore it completely. It is true that the improvement that took place in them was, in a sense, spontaneous,

for, beyond placing them in the most favourable conditions possible, nothing special was done for them. Is it to be supposed that more direct efforts might have produced better results in them, and done something, perhaps, for that much larger number in which the vision of the once deviating eye remained as feeble as ever? It is difficult to think so. The only other measure available would have been to enjoin the exclusive use of the faulty eye as long and as often as this would be tolerated. The method is an old one, and has been frequently tried, yet it may be fairly asked, Where are the results? There is certainly no general recognition of benefit obtainable by such means, but rather an acceptance as fact that an amblyopic squinting eye, whatever improvement may be effected in its position, always remains subject to visual disability.*

* The above conclusions are similar to those arrived at by Mr. Adams Frost and Dr. G. A. Berry. The former says, in reference to the exclusive use of a squinting eye, "I have not seen any great good arise from it. I have over and over again seen the vision improve slightly" ('British Medical Journal,' 1887, vol. ii, p. 663). The latter holds that, in those cases of amblyopia in which central fixation is retained, there are "two elements, one of which is permanent and the other capable of disappearing when the squinting eye is for some days used for fixation. That is to say, the amblyopia may disappear to a certain extent, but rarely entirely. The recognition of the two elements in the amblyopia of the squinting eye, in most cases at any rate, where the power of central fixation is retained, is in so far of practical importance that we may thereby see the uselessness of continuing for months, as is sometimes done, to exercise the squinting eye in order to improve its vision" (ibid., p. 666). Messrs. Lang and Barrett obtained im-

But if the great majority of those who have suffered from convergent strabismus have to reconcile themselves to a more or less serious visual deficiency in one eye, that does not imply that they are condemned to a perpetual state of monocular vision. For the binocular fusion of the two retinal images visual equality, however desirable, is not essential. The image formed on the yellow spot of an eye which suffers from relative amblyopia must always be more faintly perceived than that depicted on the yellow spot of its fellow. When, moreover, this worse eye is misdirected it will receive on its yellow spot an image other than that of the object to which the fixing eye is directed, so that what in any case would be relatively faint will be mentally "suppressed," that is, vision will be monocular. But when the visual axes have been brought to converge always upon the same object, the need for "suppression" will cease, and we have to try and substitute for the habit of suppression a habit of perception. It is not possible, as we believe, to abolish, except in rare cases, relative amblyopia; but it is possible to make the fainter impressions conveyed by the one eye practically useful to the patient by causing them to be com-

provement in the vision of the squinting eye from the wearing of glasses in three out of fourteen cases, a proportion of 21·42 per cent., and arrived at the conclusion that "in cases of concomitant convergent strabismus treatment is of value chiefly for cosmetic purposes" ('Roy. Lond. Ophthal. Hosp. Reps.,' vol. xii, p. 133, *et seq.*).

bined with the stronger ones conveyed by the other—by establishing, in short, binocular vision. This may perhaps come about spontaneously, but if so it can only be a slow process, and cannot be a frequent one. For, having learnt to rely on the one eye, the patient will discover no need to call in the aid of the other; and it is the latter, not the former, that requires assistance. It is by a system of training that the dormant perceptions must be evoked and combined with those already awake. Such training may be carried on either by the stereoscope, or by means of a red glass and lamp, aided if necessary by a prism. The principle of either method is the same, and consists in making the patient conscious of two sets of visual impressions and of the necessity of combining them into one.

Of the thirty-seven patients mentioned above only a few were available for the purpose of trying to establish binocular vision, though diplopia could be evoked in many more. In the end a successful result was obtained in eight

TABLE LIII (*cases attaining binocular vision*).

State of vision in the rectified eye.	Monolateral cases.		Alternating cases.		All cases together.	
	No.	Proportion.	No.	Proportion.	No.	Proportion.
		per cent.		per cent.		per cent.
Vision improved . .	2	33·33	1	50·00	3	37·50
,, not improved .	3	50·00	0	—	3	37·50
,, always equal .	1	16·06	1	50·00	2	25·00

cases, six of which were monocular and two were alternating; and it will be seen that this came about, although in three of the monocular cases no improvement in the vision of the formerly squinting eye had taken place. Binocular vision, therefore, does not require as a necessary condition equality of vision in the two eyes. One cannot say how many more of the thirty-seven could have been brought to the condition desired of seeing habitually with both eyes together, but it may be conjectured that the proportion of 21 per cent. does not represent the real ratio of those in whom this result could be obtained, and that, if opportunity had been given, binocular vision could have been established in a larger number than was actually the case.

It cannot be necessary to vindicate here the advantages of binocular vision; the only point to consider is whether the trouble involved in trying to establish it is too great. If we spend our efforts on all cases indiscriminately, disappointment will certainly befall us; but with reasonable care we ought to get satisfactory results. It is necessary that the degree of relative amblyopia should not be too great and that the patient should be possessed of fair intelligence and perseverance. When these are present no great amount of trouble will be required, for after the first few attempts the exercise will become one of easy routine. In any case the trouble incurred will be as nothing to the discomfort caused by

insisting on the exclusive use of a more or less amblyopic eye. We cannot but think that if some of the zeal and patience shown in trying to improve the vision of defective eyes had been devoted to making those eyes work in harmony with their fellows, far more fruitful results would have been attained.

It is in this direction—in the systematic endeavour to bring about binocular vision in those who are capable of it—that the best hope seems to lie of adding to the good that we can do to those who suffer from convergent strabismus.

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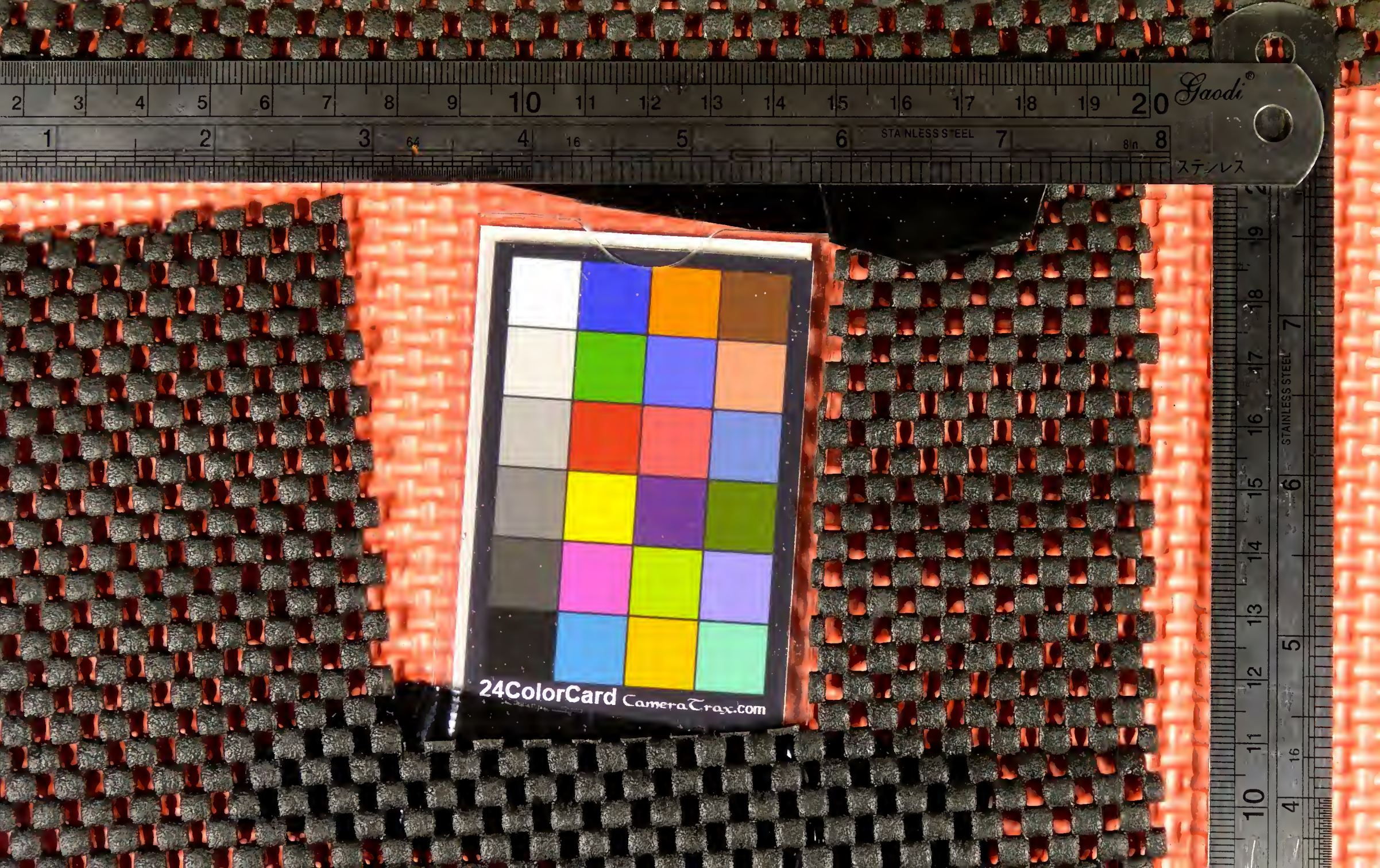
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